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CONTENTS

	PAGE
Lamb Fattening Trials on the Canterbury Plains. *T. K. Ewer* and *D. P. Sinclair*	(6)1
The Estimation of Carotene in Plant Material and Faeces. *W. A. McGillivray*	(6)31
Deterioration of Soil Structure in a South Canterbury Soil. *R. Q. Packard* and *J. D. Raeside*	(6)40
Aerial Top-dressing Trials: Equipment and Flying Techniques used and Measurement of Distribution of Phosphate. *A. F. Greenall, S. G. Quill* and *J. Stephenson*	(6)54
Soil Disinfection. XII. Effect of Fumigants on Growth of Soil Fungi in Culture. *H. Jacks* and *H. C. Smith*	(6)69
Control of Weeds in Tobacco Seedling Beds. *R. Thomson*	(6)74
Control of Lateral Growth in Flue-cured Tobacco by Chemicals. *R. Thomson*	(6)78
Changes in the Salt Content of some Saline Soils at Lake Ellesmere in Canterbury. *L. T. Evans*	(6)81
Technique for Obtaining Aseptic Seedlings. *H. W. Johnston*	(6)87
Index	(6)92
Inter-Commonwealth Post Graduate Scholarships in Science	(6)99
C.A.B. Publications	(6)100

NOTICES

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LAMB FATTENING TRIALS ON THE CANTERBURY PLAINS

By T. K. EWER* and D. P. SINCLAIR, Animal Research Division, Department of Agriculture, Wellington

[*Received for publication 30 March 1951*]

Summary

(1) Ten years' observations on fattening store lambs at the Kirwee Experimental Farm in Canterbury showed that lamb growth was more dependent on seasonal variation in the nutritional status of the feed than on any of the feeding methods examined or on the type of crop fed.

(2) Over four years, sweet blue lupin showed itself to be a fodder crop of comparable value with rape as judged by both individual lamb growth and bulk of feed produced, while chou moellier and thousand-headed kale gave similar results.

(3) During both wet and dry summers improved permanent ryegrass and clover pasture, or specially sown H1 and Italian ryegrass did not compare favourably with the grown crops either in carrying capacity or in lamb growth produced.

(4) Set (continuous) grazing was the most successful method of feeding off crops as judged by individual lamb growth. No trouble was incurred by leaving lambs on the crops when the feed was wet. Weekly break-grazing was of no benefit during the normal dry summers, but resulted in slightly increased lamb growth in two wet summers when the incidence of internal nematode parasites was higher than normal.

(5) Running lambs off the crops to pasture either overnight or during the day depressed lamb growth, but resulted in some sparing of the fodder crops.

(6) Hay and grain supplements either given on the feed or on a run-off at night were ineffectual in assisting lamb growth, except when an unlimited and uneconomical ration of good quality subterranean clover hay was given.

(7) A supplement containing cod liver oil and all the recognised mineral requirements of sheep had no beneficial effect on lamb growth when administered to individual animals or when given as a lick. One exception to the latter practice is discussed.

(8) No abnormal mortality occurred during the period of the trial.

* Now in the Veterinary Faculty, University of Queensland.

Introduction

The relatively low and uncertain rainfall of the Canterbury Plains has resulted in a system of lamb fattening which is different from the grass-land fattening commonly practised in many parts of New Zealand. Pasture growth is confined to the relatively short Spring and early Summer period, with the result that the common system of lamb fattening has become dependent upon specially grown feed crops. There is also the fact that the largest part of New Zealand's cereals and small agricultural seeds are produced in Canterbury; this results in most farms having a proportion of their acreage under the plough, and thus fattening feeds are conveniently fitted into the crop rotation.

It was in this context that there occurred in 1937 and 1938 a widespread mortality amongst fattening lambs. Deaths began to occur about the time of weaning in early January and from then the mortality gained in momentum until April, a time during which large numbers of store lambs from hill-country flocks are fattened on the plains. Not only did lambs die, but the rate of fattening generally was seriously reduced. When the freezing works closed for the season at the end of May there was a high carry-over of lambs which in a normal season would have been fattened and slaughtered.

At the time, observations were made by field officers of this department upon the nature and extent of the losses on farms over a wide section of mid-Canterbury and North Canterbury. Since the symptom complex was found to be similar to that usually associated with heavy worm infestation, a considerable series of total worm counts was done upon sick and dead lambs. The results served to confirm the belief that while pathogenic nematodes were frequently playing a part in causing the widespread unthriftiness, the number of worms found in a large proportion of the sick sheep were in themselves not sufficient to account for the symptoms shown.

It became increasingly evident that the only way in which the aetiology of this sheep disease could be properly studied was by doing experimental work on a farm in Canterbury where the various factors of management and feeding as well as the parasitological aspects would be subject to control, and could be closely studied. Therefore, it was for this purpose that the Kirwee Experimental Farm was established at the beginning of 1940. The farm was situated on medium light land typical of that found in much of the province and which had a bad record for sheep losses over the preceding three years.

General sheep feeding investigations with all ages of sheep were conducted at Kirwee until early 1949, and this paper presents the results of fattening trials with weaned store lambs carried out each year during the whole period.

The original purpose of the trials was to establish a system of practical fat-lamb management which would assist in reducing or avoiding lamb losses, and therefore during the first four years many feeding practices were investigated. Rape was the feed grown, as at that time it was easily the most popular fattening crop in Canterbury. Set grazing, i.e. leaving the lambs continuously on one sowing of a crop, was the control system of feeding adopted, and with it were compared all other methods which included a system of providing fresh breaks of feed each week designed to interrupt the life cycle of pathogenic nematodes; running the lambs off the crop to pasture at

different periods during the day or overnight; supplying various supplements of hay or grain either on the crop or on the pasture run-offs; and the giving of a comprehensive mineral supplement to eliminate the possibility of some trace element or other mineral deficiency.

In 1944, sufficient seed of the newly introduced sweet blue lupins became available, and as this crop offered the possibility of a more reliable fattening feed for this part of the country, it was grown and compared with rape under a more limited range of feeding systems. This comparison was continued until 1947, but since no serious lamb mortality had been encountered by this time, all investigations of feeding practices were discontinued, and the final two years were used to compare rape and sweet blue lupin with chou moellier, thousand-headed kale, and newly sown ryegrasses under a set grazing system.

In addition to the specially grown fattening crops, various types of permanent improved pasture were tested for their lamb-fattening qualities during 1945, 1946, and 1947.

It will be seen from the above that these lamb fattening experiments fell into three main chronological sections on grown crops, with a fourth dealing with pasture, and the results have therefore been presented under the following four headings:

(1) Rape feeding 1940–43;
(2) Comparison of rape and sweet blue lupin 1944–47;
(3) Comparison of rape, sweet blue lupin, chou moellier, thousand-headed kale, and new sown ryegrasses 1948–49;
(4) Lamb fattening on pasture 1945–47.

The parasitological aspects of Sections I and II have been reported previously (Ewer and Sinclair, 1951).

EXPERIMENTAL PROCEDURE

The following descriptions of experimental procedure cover all four sections.

Crop Production and Methods of Feeding

Each year, between 40 and 50 acres were sown down to fattening crops. Except for 1940, the rape (and later sweet blue lupin) was sown in four breaks at approximately three-weekly intervals from late October onwards, in order to produce under normal conditions a continuous supply of feed for at least ten weeks from early January when store lambs are first available. However, due to weather conditions, this object was not always attained and the experimental feeding period was in practice limited entirely by crop survival. Rape was sown at the rate of 2½ lb. per acre and sweet blue lupin at 2 bushels per acre, both being drilled with 1 cwt. superphosphate per acre.

Equal areas of feed were allotted to each experimental group, and as soon as any one of these had been consumed, all experimental groups were shifted to a fresh break, or, in the case of the last break, the experiment was terminated. Thus it was assured that no one group was short of feed at any time.

Owing to the above-mentioned feature of experimental design, no account was taken of lambs fattened per acre, nor until 1949 was any attempt made to measure the bulk of feed on any break. Subjective

observations, however, were made and recorded, and these have been used to indicate the maturity of the crops in various years and the relative amounts of feed available.

Breed of Lambs used in Experiments

Throughout all these trials, either pure Corriedale or half-bred type or the Corriedale-Southdown cross lambs were used, and no account has been taken of them as separate breeds. It might be thought that the down-cross lambs would have introduced bias into the results in favour of that breed, but the work of McMeekan and Walker (1944), and later, Coop and Clark (1949), both on lambs from the Kirwee farm, has shown that, post weaning, the early fattening propensities of the Southdown are no longer apparent, and that the growth rates of the two breeds are closely similar.

Selection of Experimental Groups

At the beginning of each year's trial all the available lambs were weighed, and, within the limits of desired group size and number, those of extreme weight discarded while the remainder were randomized into equal groups entirely upon a weight basis. This procedure gave mean groups weights within a range of 0·5 lb., and a weight range within a group of between 15 and 18 lb.

Experimental Measurements

Three criteria of measurement were used to judge the value of any treatment: weight gain, carcase weight, and incidence of mortality.

Following the initial weighing and randomization into groups, the lambs were placed on their respective treatments and feeds, and thereafter were weighed at approximately fortnightly intervals until the end of the experiment. When changes to fresh breaks of feed were necessary between weighing dates, an extra weighing was carried out.

For the first five years, a fat lamb buyer from the freezing works selected lambs for slaughter at the conclusion of the experiments. For reasons mentioned later this practice was not satisfactory, and for the remaining years all lambs were killed. All deaths were recorded, and where possible the cause of death diagnosed by post mortem and laboratory examinations.

Feeding of Supplements

Hay was fed in covered racks and grain in open troughs. Each day except Sunday supplements were weighed out and given to the groups concerned, a double ration being given on Saturdays. The following day residues were collected and weighed, and thus the total group consumption was estimated. Irrespective of consumption, the planned amounts of hay or grain were supplied to the lambs. Though obviously uneconomical from the practical farming point of view, such a programme allowed for the wide day-to-day variation in consumption which occurred, and also demonstrates the great difficulty encountered in persuading lambs on green feed to eat the less palatable supplements.

Presentation of Results

All results in terms of live weight are presented separately for each year as mean initial weight and mean total weight gain, the latter also being converted to mean weight-gain per day in order to facilitate year-to-year comparisons. Interim mean weights have not been pre-

sented in tabular form, but to illustrate growth changes which took place in relation to the various breaks of feed and also the wide seasonal variation in growth, graphs of the periodic weight gains of the set grazed (central) group on rape, this feed being the only one grown every year, are presented in Fig. I, together with a table showing the monthly rainfall totals during the period November to March for each year. Both these are included as an appendix to Section III.

For the earlier years, mean carcase-weights have not been presented. The figures derived from lambs selected for killing by a freezing-works buyer gave no information as to the true carcase-weight/live-weight ratio of each group, and served only to indicate the percentage of lambs passed as suitable for killing by one fat-lamb buyer.

In later years when all lambs were killed, mean carcase-weights have been shown. Except in 1940, the incidence of second grade carcases even when all lambs were killed was negligible and has not been considered.

Analysis of Results

The weight-gains of each experiment have been subjected to analyses of variance. In the early years when rape alone was fed, a simple analysis of single classification has been used and from the error term obtained and the 1 per cent level of " t " for the appropriate degrees of freedom, a significant difference between any pair of groups has been calculated. In a large series of trials such as these, it is thought wise to consider only those differences which exceeded the 1 per cent level of significance.

When the experiments contained two or more criteria of classification, appropriate methods of analysis have been used. Throughout all the experiments until 1946, the value of anthelminthic treatment was tested by drenching half of each group. The overall results of this have been reported, but have not been considered in this paper. However, in the analyses due account has been taken of drenched and undrenched sub-classes when calculating error variance in the years 1943 and 1945 when drenching was shown to have had some effect.

In each year the analysis is shown with the results.

SECTION I. RAPE FEEDING TRIALS, 1940-43

1940 Trial

Ten groups of 40 lambs were selected from a mob of 550 Corriedale store lambs purchased at public auction and were put on to the treatment as set out in Table I. The rape was sown in two breaks, both of which produced poor crops. Dry weather and aphis contributed to its rapid disappearance, and the experiment was maintained for only eight weeks.

The pasture run-off of Groups 2 and 3 was an old paddock of browntop and subterranean clover and in the earlier part of the trial contained a bulk of dry feed with some green clover.

Groups 4–7 and Groups 8–10 were grazed together during the day, brought into the sheep yards at night, and there given their respective supplements.

To eliminate the possibility of some trace element or other mineral deficiency, a mineral and vitamin supplement was administered to individual lambs in Gronp 6 three times weekly. Each dose consisted

of 17 g of a comprehensive mineral mixture and 10 ml cod liver oil. The quantities in the former were necessarily rather arbitrary, but were designed to provide maximum possible requirements. Each dose contained approximately the following ingredients:—

$CaHPO_4$, 9·0g; $MgSO_4$, 2·4g; $FeSO_4$, 0.24g; $CuSO_4$, 0.07g; $MnSO_4$, 0·08g; $ZnSO_4$, 0·09g; $CoSO_4$, 0·005g; $NiSO_4$, 0·005g; As_2O_3, 0·001g; H_3BO_3, 0·11g; KI, 0·04g; NaCl, 5·0g.

At first an attempt was made to give the mixture in dry powder form in order to avoid loss through interaction of KI and $CuSO_4$. This, however, was found impracticable, and thereafter the mixture was drenched as a suspension in water. Results and analyses are set out in Table I.

TABLE I. 1940 FEEDING TRIAL WITH RAPE
(16 Jan. - 12 Mar. - 56 days).

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
1	RAPE Set grazed	-	49.3	18.7	0.33
2	RAPE Run off to pasture at night	-	48.8	17.4	0.31
3	RAPE & WATER Run off to pasture at night	Consumption negligible	49.2	19.8	0.35
4	RAPE, WEEKLY BREAKS	-	49.3	18.6	0.33
5	RAPE, WEEKLY BREAKS + ½ lb Oats per lamb per day	0.2	49.2	13.4	0.24
6	RAPE, WEEKLY BREAKS + Mineral & Vitamin supplement		49.3	19.0	0.34
7	RAPE, WEEKLY BREAKS + ½ lb Lucerne hay per lamb per day	0.4	49.2	18.5	0.33
8	RAPE & ITALIAN RYEGRASS, WEEKLY BREAKS	-	49.0	15.8	0.28
9	RAPE & ITALIAN RYEGRASS, WEEKLY BREAKS + ½ lb oats per lamb per day	0.2	49.2	15.3	0.27
10	RAPE & ITALIAN RYEGRASS, WEEKLY BREAKS + ½ lb lucerne hay per lamb per day	0.4	49.1	16.6	0.30

Analysis of Variance of weight gains

Source of Variation	df	ss	ms	F
Total	396	11,103.		
Groups	9	1,977.6	219.73	9.318H.S.
Within groups (error)	387	9,125.4	23.58	

Significant difference ($P<.01$) between any pair of groups = 2.8 lb

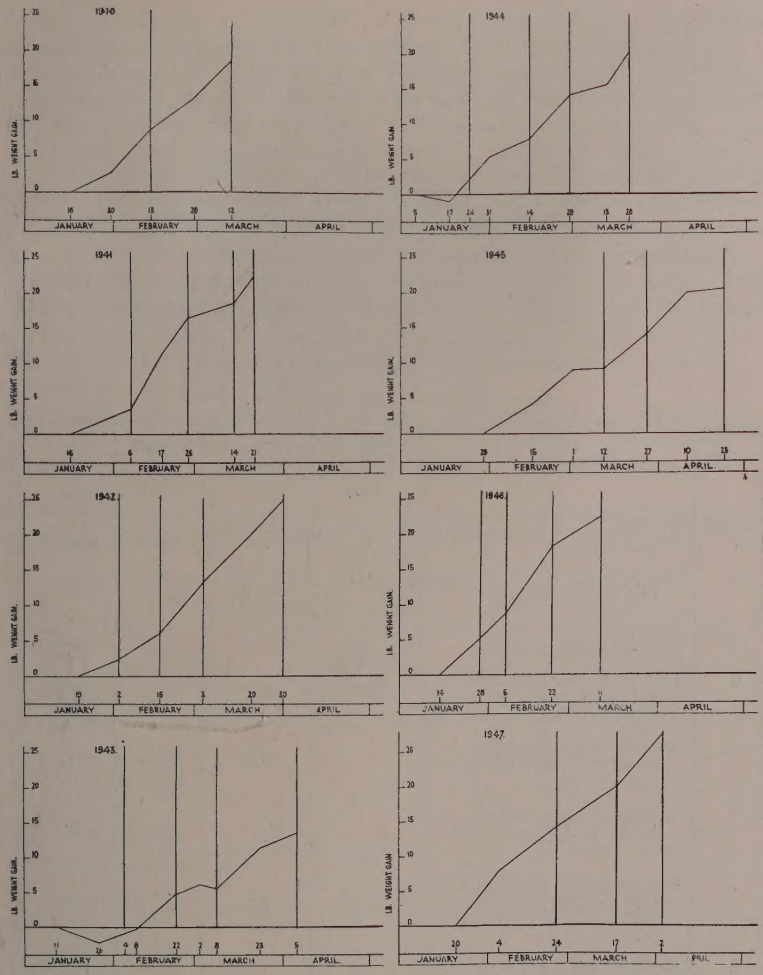

FIG. 1. Growth rates of set-grazed control groups of lambs fed on rape. 1940-47.

Results: It can be seen that no group made a significantly better gain than the set-grazed group on rape alone; in fact, both those on the area oversown with Italian ryegrass and those given an oats supplement on rape made significantly poorer weight gains.

Break grazing, run off to pasture, and available water were all quite ineffectual in bringing about better rate of growth.

Less than 50 per cent of the lambs were selected as fats, but this was due to the shortness of the feeding period and not to a general unthriftiness. No mortality occurred during the experiment except for four lambs in Group 6 which died from pneumonia following forced administration of the dry mineral mixture. The appearance of the rape in both breaks was closely similar, and as shown in Fig. 1 the weight gains made on each were also similar.

1941 Trial

Three hundred Corriedale lambs were purchased privately from a hill country flock, and from them nine groups of 25 were selected. The lambs were small but very even, and showed no sign of unthriftiness. It was hoped that a smaller group size, and the four sowings of rape, would permit of a longer fattening period, but again dry weather from mid-February and aphis infestation brought about a premature wastage of the last two breaks; consequently, the experiment could not be maintained for more than nine weeks.

Table II shows the group treatments and results. It will be seen that except for an oversowing of Italian ryegrass, a programme similar to that of 1940 was followed. Group 5 was given the same

TABLE II. 1941 FEEDING TRIAL WITH RAPE

(16 Jan. to 21 Mar. - 64 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
1	Set grazing	-	47.9	22.4	0.35
2	Set grazing run off to pasture at night		48.1	17.9	0.28
3	Weekly break grazing	-	48.0	23.8	0.37
4	Weekly break grazing + ½ lb clover hay per lamb per day	0.45	48.2	19.8	0.31
5	Weekly break grazing + mineral and vitamin supplement		48.0	17.4	0.27
6	Weekly break grazing + run off to pasture at night		48.0	18.4	0.29
7	Weekly break grazing run off to pasture at night + ½ lb oats per day	0.25	48.0	17.3	0.27
8	Weekly break grazing run off to pasture at night + ½ lb barley per day	0.44	48.0	17.4	0.27
9	Weekly break grazing run off to pasture at night + ½ lb lucerne hay	0.28	48.2	20.5	0.32

Analysis of Variance of weight gains

Source of Variation	df	ss	ms	F
Total	219	5233.5		
Groups	8	1057.8	132.22	6.68 H.S.
Within groups (error)	211	4175.7	19.79	

Significant difference ($P<.01$) between any pair of groups = 3.3 lb

mineral and vitamin supplement but Groups 7, 8 and 9 were given their hay and grain supplements on their run-off overnight instead of in the yards as previously. The run-off was again on a paddock of old brown-top and subterranean clover, but with the dry weather prevailing little feed was available on it.

Results: The weight gains from set grazing and break grazing were similar, and were both significantly superior to those from all other treatments. No large differences existed between the groups given run-offs with or without supplements, although Group 9 given lucerne hay appeared to do somewhat better than the others. A mineral and cod liver oil supplement had no beneficial effect.

Fig. I shows that growth was more vigorous on Breaks 2 and 4, than on Breaks 1 and 3. No major differences were observed in the appearance of the breaks other than that the last three were all over mature at the time of feeding.

There was no evidence of unthriftiness during the trial. One lamb died of enterotoxaemia and two, due to inhalation of the mineral supplement.

1942 Trial

Seven groups of 30 lambs were selected from a mob of 380 forward

TABLE III. 1942 FEEDING TRIAL WITH RAPE
(Period 19 Jan. to 30 Mar. - 70 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
1	Set grazing	-	53.8	25.1	0.36
2	Set grazing + sub.clover hay ad lib.	0.56	53.9	28.9	0.41
3	Set grazing + ½ lb sub.clover hay per lamb per day	0.40	53.7	25.5	0.36
4	Set grazing + ½ lb oats per lamb per day	0.1	53.9	23.6	0.34
5	Set grazing 4 hr run off to pasture daily	-	54.2	24.3	0.35
6	Set grazing Run off to pasture all night	-	54.2	22.4	0.32
7	Set grazing Run off to pasture all day (8a.m.-5p.m.)	-	54.1	21.1	0.30

Analysis of Variance of weight gains

Source of Variation	df	ss	ms	F
Total	204	6835		
Between groups	6	1113	185.50	
Within groups (error)	198	5712	28.85	6.43 H.S.

Significant difference ($P < .01$) between any pair of groups = 3.6 lb

store Corriedale lambs. The rape was the best so far grown. The first two breaks were somewhat stunted due to dry weather in the early growing period, but following adequate rainfall in late December and January the last two breaks were well grown and gave abundant feed.

The treatments and results are set out in Table III. It will be seen that the experimental design was altered from the previous years. The examination of break-grazing, and the effects of a mineral and vitamin supplement was discontinued and the experiment confined to a comparison of an economic ½lb ration of hay with an *ad lib* ration, and to an examination of the influence of run-off time upon fattening rate. The run-off was a similar pasture to those used previously, namely, brown-top and sparse subterranean clover.

Subterranean clover hay was used and was the same as that described by Lancaster and Adams (1943) as being of unusually good quality.

Results: An examination of Table III shows that, although consumption was only 0·56 lb. per lamb per day, an *ad lib* ration of hay brought about a significant increase in weight gain, while a ½ lb. ration which was nearly all consumed was without effect. As weight of hay consumed was similar, the cause of this difference is not known.

The consumption of oats was negligible and without significant effect, although as in the past two years the weight gain of the group concerned was smaller than that of the control group. A four-hour run-off had no effect but an all-day run-off produced significantly poorer gains.

Fig. I shows that the growth rate on the last two breaks was approximately double that on the first two. Two lambs died during the experiment, the cause in each case being enterotoxaemia.

1943 Trial

Seven groups of 30 were selected from a mob of 400 mixed Corriedale and Corriedale-Southdown cross lambs which had been reared on the farm. Although the mean initial weight was higher than previously, the lambs were not thriving as evidenced by the fact that so many were available on the property. Under normal conditions 40 per cent or more of lambs were sold fat off their mothers at weaning, but on this occasion few lambs were fit for killing. This general unthriftiness was associated with unusually well spread summer rainfall and plentiful pasture growth.

The first three breaks of rape grew vigorously and were dense and green at the time of feeding, but the fourth break was overtaken by dry weather with the same result as in the past.

Two of the groups selected were used in a preliminary experiment on sweet blue lupin, but only a limited area could be sown with the small amount of seed available. The feeding period lasted only six weeks during which time growth of all lambs was poor, and, therefore, no information as to the true value of this feed could be obtained.

Table IV sets out the treatments and results from the groups on rape. The only new feature was a return to an examination of break-grazing under the unusual feed conditions prevailing.

Results: A group-to-group comparison reveals that under the lush feed conditions prevailing, a system of break grazing brought about a

TABLE IV. 1943 FEEDING TRIAL WITH RAPE
(Period 11 Jan. to 5 April - 84 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
1	Set grazing	-	56.6	13.7	0.16
2	Set grazing + sub. clover hay ad lib.	0.4	55.7	14.4	0.17
3	Set grazing + run off 4 hrs daily	-	56.0	12.3	0.15
4	Set grazing + run off to pasture at night	-	56.2	8.7	0.10
5	Weekly break grazing	-	55.3	17.1	0.20

Analysis of Variance of weight gains on Rape

Source of Variation	df	ss	ms	
Total	141	6881		
Subclasses *	9	2164.5	240.5	H.S.
Error	132	4716.5	35.73	

Significant difference between any pair of groups = 4.0 lb

* Owing to the significant effect of drenching this year (1) drenched and undrenched subclasses have been taken into account when calculating the error mean square

significant ($P < \cdot 05$) increase in weight gain, while a run-off to pasture at night significantly reduced it.

An *ad lib* ration of hay and a four-hour daily run-off had no influence on weight-gain.

The most striking feature of this year's experiments was the extremely poor weight-gains of all lambs. As shown by Fig. 1, growth was not consistent until the last break was fed. Practically the whole difference between set and break grazing occurred during this period.

In spite of much evidence of unthriftiness, no serious mortality occurred. Early in the trial, five lambs died following extreme scouring and progressive emaciation, the typical symptoms of the disease of 1937-38. Two further lambs died of enterotoxaemia.

SECTION II. COMPARISON OF RAPE AND SWEET BLUE LUPIN, 1944–47.

Introduction

In the foregoing section there is ample evidence that rape could not be relied upon to supply a guaranteed period of feeding. Its susceptibility to aphis infestation and its rapid desiccation in dry weather, which greatly reduced its carrying capacity although not appearing to decrease its nutritive value, made it far from satisfactory as a lamb-fattening feed.

Following the advent of the sweet blue lupin from Germany and its successful propagation in Canterbury, preliminary fattening trials

with it were conducted at Lincoln College during 1941 and 1942; the results obtained (1942) suggested that it was a more valuable fattening feed than rape. Over the short period tested, sweet blue lupin gave a 50 per cent higher stocking rate and produced a greater rate of growth than rape; in addition, of course, there was its value as a fertility restoring crop.

The aforementioned trials were carried out on heavy land, but it was felt that this new feed offered great possibilities as a substitute for rape on light land and under the dry summer conditions of Kirwee which typified a large portion of the Canterbury plains.

Sufficient seed for a complete fattening trial became available for the summer of 1944, and from then until 1947 it was compared for its fattening qualities with rape over a limited range of feeding practices. The preliminary trial of 1943 and the findings of the Lincoln College workers suggested that the best results could be obtained by sowing the sweet blue lupin at the same time as rape. This programme was followed throughout.

TABLE V. 1944 FEEDING TRIAL WITH RAPE AND SWEET BLUE LUPINS
(Period 6 Jan. to 20 Mar. - 74 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
RAPE					
1	Set grazing		58.3	20.7	0.28
2	Set grazing + run off to pasture at night		58.3	15.4	0.21
3	Weekly break grazing		58.3	22.1	0.30
4	Weekly break grazing + 1 lb clover hay per lamb per day	0.2	58.2	20.6	0.28
SWEET BLUE LUPINS					
1	Set grazing		58.2	21.0	0.28
2	Set grazing + run off to pasture at night		57.9	14.4	0.19
3	Weekly break grazing		58.5	22.4	0.30
4	Weekly break grazing + 1 lb clover hay per lamb per day	0.2	58.4	21.7	0.29

Analysis of Variance of weight gains on Rape and Sweet Blue Lupins

Source	df	ss	ms
Total	228	7379	
Between treatments	3	1919	639.66 H.S.
Between feeds	1	3	3.0
Interaction	3	34	11.33
Within groups (error)	221	5423	24.54

Significant difference between any pair of groups = 3.3 lb

1944 Trial

Immediately following weaning, eight groups of 30 lambs were selected from a mob of 300 mixed Corriedale and Corriedale-Southdown cross lambs reared on the farm. Equal areas of rape and sweet blue lupin were sown in four breaks and the breaks of both feeds were fed off concurrently.

Extremely dry weather during November, December and January had its usual ill effects on the first two breaks of rape which were stunted and purplish though not heavily infested with aphis. The sweet blue lupin in the same areas withstood the conditions rather better, and, although not tall, was dense and just coming into flower at the time of feeding.

Following heavy rain in early February, a most spectacular period of growth took place, and the last two breaks of each feed were both succulent and prolific. The treatments and results from both feeds are set out in Table V.

Results: Remarkably similar results were obtained from both rape and sweet blue lupin, the only noticeable feature being the significantly poorer weight-gains of both groups given a run-off to pasture at night. No other significant differences appeared in the results.

The average weight-gain of set-grazed lambs of 0·28 lb. per day was poor when compared with those obtained in the earlier years 1940–1942. This was not associated with any general unthriftiness, but, as shown by Fig. 1 was due to a temporary loss of weight during the first fortnight's feeding which, possibly, was caused by an upset due to weaning. Normally, with bought-in lambs, some period had elapsed between weaning and the commencement of the trial, but on this occasion, owing to the early maturity of the rape crop, lambs were put on to experimental treatments immediately following weaning. Ignoring the first period, and taking growth between 17 January and 20 March, a comparable weight gain of 0·35 lb. per day was obtained.

During the experiment five lambs died of enterotoxaemia.

1945 Trial

Ten groups of 30 were selected from a mob of Corriedale-Southdown cross lambs bred on the farm and weaned a fortnight previously. The usual four breaks of rape and sweet blue lupin were sown, but frequent rainfall throughout November and December delayed their cultivation, sowing and subsequent maturing, with the result that they were not ready for feeding until the end of January. The season (until the end of March) was unusually wet, and the bulk of feed on both crops was relatively enormous. This may be gauged by the fact that the first break of rape carried 25 lambs per acre for six weeks, and only three of the four breaks of each feed were utilized for this experiment.

Substantially the same experimental design as in 1944 was followed, except that one group on rape was given hay on a run-off overnight, and an extra group was included to graze "immature" rape.

The purpose of this procedure was to see whether rape in a soft green condition was of a lower nutritive value than mature rape as the results of 1943 suggested. It was a strong belief amongst local farmers that this type of rape, common in a wet summer, was responsible for the general unthriftiness amongst lambs.

The group concerned was grazed on the last two breaks of rape some four weeks ahead of the main experimental feeding, but unfortunately the relative immaturity of these breaks was largely a matter of age and height of plant, and not of colour or dry-matter content. The earlier breaks of rape continued to grow, and the normal purplish tinge of mature plants had not developed when it became necessary to commence experimental feeding, nor did it develop during the course of the experiment.

As would be expected, the pasture run-off this year contained plentiful clover. The experimental treatments and results are set out in Table VI. Growth rates for both set- and break-grazed lambs are shown in Fig. 1.

TABLE VI. 1945 FEEDING TRIAL WITH RAPE AND SWEET BLUE LUPINS
(Period 29 Jan. to 23 April - 84 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
RAPE					
1	Set grazing	-	58.6	20.5	0.24
2	Set grazing + run off to pasture at night	-	58.5	16.2	0.19
3	Weekly break grazing	-	58.6	22.8	0.27
4	Weekly break grazing + clover hay ad lib	0.52	58.2	23.5	0.28
5	Set grazing + run off to pasture at night + hay ad lib in run off	0.29	58.1	15.8	0.19
6	*Set grazing	-	58.5	18.4	0.32
SWEET BLUE LUPINS					
1	Set grazing	-	58.5	19.3	0.23
2	Set grazing + run off to pasture at night	-	58.5	15.4	0.18
3	Weekly break grazing	-	58.7	22.6	0.27
4	Weekly break grazing + clover hay ad lib	0.43	58.6	25.4	0.30

* Immature rape - Period 29 Jan. to 27 Mar. - 57 days.

Analysis of Variance of weight gains on Rape and Sweet Blue Lupins (without groups 5 and 6)

Source of Variation	df	ss	ms
Total	223	9391	
Between treatments	3	2490	830.0 H.S.
Between feeds	1	0.7	0.7
Interaction	3	87.7	28.93
Within subclasses	216	6092	28.20

Significant difference between any two groups = 3.6 lb

Results: Similar results were obtained from both feeds. A run-off to pasture at night with or without a hay supplement again produced significantly smaller weight gains, but on this occasion weekly break grazing brought about increased weight gains which, though consistent, were not significant. The combined effects of break grazing plus hay gave better gains which were significant, but the apparently greater effectiveness of a hay ration on sweet blue lupin was not confirmed by significant interaction in the analysis. Over all, the rate of growth was poor, and, as shown in Fig. 1, was caused largely by the failure of the lambs to put on weight over the last fortnight on Breaks 1 and 3, where in each case a much longer feeding period than usual had been maintained. It was shown that re-infestation of set grazed lambs with parasitic nematodes took place during the long period of feeding on Break 1 (Ewer and Sinclair, 1949), but the similar performance of break-grazed lambs precludes that factor as the sole cause of the poor growth, and it is assumed that other factors associated with rape itself were involved.

"Immature" rape produced no ill effects other than a photo sensitization of the ears of some lambs, and in fact proved to be a better feed than the older rape. The weight-gain of Group 6 was significantly greater than that of Group 1 over the same period. No mortality occurred which could be associated with the failure of the lambs to thrive, the five recorded deaths all being due to enterotoxaemia.

1946 Trial

A week after weaning groups of 20 Corriedale-Southdown cross lambs were selected from all those remaining after the early drafts of fat lambs had been taken off their mothers. Owing to a large and unexpected number of lambs being fat, the remainder were insufficient for our purpose, and the group size was necessarily reduced.

The same four breaks of rape and sweet blue lupin were sown, but exceptionally dry weather during November caused the first two of rape to be sparse, stunted and over mature at the time of feeding. The third was somewhat better, though heavily infested with aphis, and the last, which benefited from high December rainfall, was fairly prolific and succulent. The lupin in all breaks was moderately well grown, though the fourth was shorter and leafier than usual. As the feeding period was limited, due to the failure of the first break of rape, the third break of lupin was not required for this experiment.

This year, the experimental design was considerably altered in that four set-grazed groups on both feeds were involved in a comprehensive examination of phenothiazine drenching at different levels. All other treatment groups were drenched. In the past, half groups had invariably been drenched, and it has been possible to ignore anthelminthic effect when making group-to-group comparisons, but on this occasion when whole groups were drenched, it has been necessary to include results from drenched set-grazed groups which, though irrelevant to this section, demonstrate that the effect of drenching was nil; consequently the usual group comparisons could be made.

The run-off groups instead of being compulsorily removed each night were given free access to adjoining pasture. Group 3 on rape was seen to spend some time on the run-off, but Group 7 on lupin, as

far as was observed, did not leave the feed. The details of treatment, results, and analysis are presented in Table VII.

TABLE VII. 1946 FEEDING TRIAL WITH RAPE AND SWEET BLUE LUPINS
(Period 14 Jan. to 11 Mar. - 56 days)

Group	TREATMENT	Supplement eaten (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)	Carcase weight (lb)
RAPE						
1	Set grazing control	-	55.3	22.5	0.40	36.7
2	Set grazing drenched 40 g Phenothiazine		55.5	21.5	0.38	36.5
3	Set grazing run off to pasture at will drenched 40 g Phenothiazine	-	55.4	17.5	0.31	35.3
4	Weekly break grazing + lucerne hay ad lib drenched 40 g Phenothiazine	0.3	55.5	20.1	0.36	36.1
SWEET BLUE LUPINS						
5	Set grazing control	-	55.3	20.8	0.37	35.3
6	Set grazing drenched 40 g Phenothiazine	-	55.3	22.2	0.40	36.4
7	Set grazing + run off to pasture at will drenched 40 g Phenothiazine	-	55.6	21.5	0.38	36.4
8	Weekly break grazing + lucerne hay ad lib drenched 40 g Phenothiazine	0.2	55.4	21.9	0.39	36.4

Analysis of Variance of weight gain on Rape and Sweet Blue Lupins

Source of Variation	df	ss	ms	F
Total	156	4642		
Between treatments	3	136	45.33	1.62 NS
Between feeds	1	61	61	2.18 NS
Interaction	3	173	57.67	2.06 NS
Within groups (error)	149	4270	27.99	

Significant difference between any pair of groups = 4.3 lb

Results: Rape and sweet blue lupin produced closely similar weight-gains under both set- and break-grazing systems. A "t" test comparing Groups 1 and 3 showed that a free access to pasture of which the lambs availed themselves brought about significantly poorer weight-gains, but otherwise there were no significant differences between treatments.

In spite of the earlier rape being very poor, stunted, over-mature and infested with aphis, the lambs grew extremely well on it, but, as shown in Fig. 1, when put on the last and most succulent break, their rate of growth slackened. The gain of 0·40 lb. per lamb per day

was the best then attained, and that on a crop which judged by appearance was the poorest so far grown.

Two lambs died during the experiment, one from enterotoxaemia, and the other from an unknown cause.

1947 Trial

As insufficient lambs were available on the property, 400 were purchased in a single line. They were a half-bred type, but bigger framed and "leggier" than any used previously. After a few days on the farm they were divided into groups of 30, and put on to feed on 26 January.

The weather during November and December had been abnormally cold, and growth of rape and lupin was slow. The rape, however, recovered quickly during the early part of January and was green and plentiful throughout the experiment, but the lupins went rapidly to maturity without much production of their usual leafy growth, and at the time of feeding on each break were either well in flower or past that stage with green seed pods already formed.

Only three breaks of each feed were required for this experiment. The experimental design contained a final comparison of set-grazing with weekly break-grazing and also with the English system of break-grazing generally known as "folding" which consists of giving a small area of fresh green feed to the lambs each day. It also contained a return to investigating the value of giving lambs a comprehensive mineral salt lick.

Although no known mineral deficiency amongst sheep in Canterbury had been established, it was still the practice of many farmers to expose a variety of licks to their fattening lambs, often with strong claims as to their therapeutic value. Therefore, it was decided to test once more the value of the lick containing all the known elements required by the grazing animal, taking precautions this time to avoid interaction of $CuSO_4$ with KI. One group on each feed was given a mineral mixture similar to that of 1940–41. It was not administered to individual lambs but exposed as two separate licks in boxes on the feed, one containing $CuSO_4$, $CoSO_4$, etc., mixed with common salt, and the other containing KI mixed with $Ca_3(PO_4)_2$ and boneflour. The former mixture was readily eaten in the amount exposed, which was designed to supply all theoretical requirements. The latter mixture was evidently unpalatable and very little was eaten.

The results, weight-gains, etc., are shown in Table VIII and growth in relation to the various breaks of feed are shown in Fig. 1.

Results: The analysis shows that, for the first time, rape produced significantly greater weight-gains than did sweet blue lupins. As shown in Fig. 1 the larger part of the difference developed on the last break and was due, possibly, to the over-maturity and stalkiness of the latter crop at the time of feeding. Set- and break-grazing again produced similar results, but the system of folding brought about the anomalous result of a marked reduction of weight-gain on rape and no reduction on sweet blue lupin.

The over-all response to the comprehensive mineral salt lick of Groups 2 and 6 was highly significant, but it was considerably greater on sweet blue lupin than on rape. Growth of set-grazed lambs on

TABLE VIII. 1947 FEEDING TRIAL WITH RAPE AND SWEET BLUE LUPINS

(Period 20 Jan. to 2 April - 72 days)

Group	TREATMENT	Supplement eaten	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)	Carcase weight (lb)
RAPE						
1	Set grazing		54.8	27.7	0.38	38.5
2	Set grazing + mineral salt lick ad lib		55.1	30.5	0.42	40.6
3	Folding		54.7	20.2	0.28	36.4
4	Weekly break grazing + 1 lb lucerne hay per day	0.25	54.7	26.0	0.36	38.4
SWEET BLUE LUPINS						
5	Set grazing		55.4	20.1	0.28	36.0
6	Set grazing + mineral salt lick ad lib	-	54.8	25.2	0.35	37.2
7	Folding		54.8	20.0	0.28	35.8
8	Weekly break grazing + 1 lb lucerne hay per day	0.30	54.5	20.8	0.29	35.9

Analysis of Variance of weight gains on Rape and Sweet Blue Lupins

Source of Variation	df	ss	ms
Total	233	8188	
Between treatments	3	1800	600.0 H.S.
Between feeds	1	1270	1270.0 H.S.
Interaction	3	440	146.67 H.S.
Within groups (error)	226	4678	20.70

Significant difference between any pair of groups = 3.1 lb

rape was vigorous and no unthriftiness was seen. Four lambs died during the experiment, enterotoxaemia again being the cause.

1948 Trial

No further comparison of feeding methods on rape and sweet blue lupin was made, but owing to the highly significant response to a mineral salt lick on the latter feed, this part of the 1947 experiment was repeated.

Two groups of 50 Corriedale-Southdown cross lambs were fed on sweet blue lupin for 47 days one being supplied with the licks as in 1947, except that the mixture containing KI and boneflour had added to it common salt in order to render it more palatable. The group concerned consumed 19 lb. of the lick containing KI, and 27·5 lb. of the lick containing $CuSO_4$, etc., and, as shown in Table VIIIA these amounts produced no improvement in weight-gain.

TABLE VIIIA. 1948 FEEDING TRIAL WITH SWEET BLUE LUPIN AND MINERAL LICK.

(Period: 7 January to 23 February)

Group	Initial Weight (lb.)	Weight gain (lb.)	Gain per day (lb.)	Carcase weight (lb.)
1. Mineral lick	56.5	15.4	0.33	35.7
2. Control	55.6	15.8	0.34	34.7

Section III.—Comparison of Rape, Sweet Blue Lupin, Chou Moellier, Thousand-headed Kale, Italian Ryegrass and Short Rotation Ryegrass

Introduction

At the conclusion of the eight years' observations described, all hope of a recurrence of the Canterbury lamb mortality of 1937–38 was abandoned; it was then decided to take advantage of the remaining two years' tenancy of the farm to compare critically the fattening qualities of rape and sweet blue lupin with these other crops and grasses quite widely grown for winter feeding purposes, but not generally used as fattening feeds.

Approximately 15–20,000 acres of chou moellier and kale were then grown annually in Canterbury, but little information as to their value as fattening crops was available; no controlled feeding trials had been done with them, and the only recorded observations related to trials carried out by Greenwood (1927) in the Awatere district of Marlborough some years previously. These compared rape with a range of other crops on the sole basis of monetary return, and though valuable for the district concerned, have little significance when related to the different condition of Canterbury.

Experimental Procedure

Corriedale-Southdown cross lambs bred on the farm were used each year, and the usual experimental procedure was followed except that weighings were not made fortnightly, but only at the end of each break's feeding. Equal areas of the six feeds were sown in two breaks in one paddock. The same amounts of rape and sweet blue lupin as used previously, viz. 2½ lb. chou moellier and kale, and 1 bushel of the ryegrasses, were sown per acre.

In 1948, the area of sweet blue lupin failed to grow, but as in another area of the farm this feed was also being used for the mineral salt lick experiment over the same period and approximately at the same rate of stocking, the control group of that trial has been used for comparative purposes.

Very dry Decembers were experienced in both 1947 and 1948, and consequently the bulk of feed on all crops was not great. In 1948 it was observed that chou moellier and kale withstood the dry conditions better than the other feeds, so in 1949 an attempt was made to measure production, and incidentally consumption, per acre by cutting, weighing, and drying a series of random square-yard samples before and after feeding. On the second breaks, the desiccation of all the feeds was so great that no attempt was made to measure the little edible matter remaining when feeding was concluded. Experimental details and results in terms of weight are presented in Table IX.

Estimated edible matter production and dry matter content of the feeds in 1949 are presented in Table X, and the weight increases on the different breaks are shown in Fig. 2.

TABLE IX. FATTENING VALUE OF VARIOUS CROPS AND PASTURES

Trial A. On 2 Breaks of 1.75 ac. over period 7 Jan. to 23 Feb.- 47 days

Trial B. On 2 Breaks of 2.7 ac. over period 12 Jan.to 25 Feb.- 44 days

Group	No.in Group	Type of feed	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)	Carcase weight (lb)
TRIAL A						
1	20	Chou moellier	56.8	12.9	0.27	32.3
2	21	Kale	56.1	13.1	0.28	32.6
3	21	Rape	55.4	14.7	0.31	33.4
4	55	Sweet blue lupin 2 breaks of 4.0 ac.	55.6	15.4	0.33	34.1
5	19	Italian ryegrass	55.1	9.9	0.21	30.7
6	21	Short Rotation Ryegrass	55.4	10.9	0.23	31.5
		Error mean square = 12.51				
		Significant difference any pair of groups = 2.9 lb				
TRIAL B						
1	43	Chou moellier	56.6	22.5	0.51	38.0
2	41	Kale	56.5	22.9	0.52	37.5
3	40	Rape	55.8	20.8	0.47	36.9
4	41	Sweet Blue lupin	55.8	20.5	0.46	36.0
5	43	Italian ryegrass	56.6	16.3	0.37	32.4
6	42	Short Rotation ryegrass	55.6	15.8	0.36	32.3
		Error mean square = 20.49				
		Significant difference any pair of groups = 2.6 lb.				

TABLE X. COMPOSITION OF FEED FROM VARIOUS CROPS

Type of Feed	Break	Total E.M per acre (tons)	D.M (%)	Total D.M per acre (tons)	Total D.M consumed (tons)
Chou moellier	1	8.4	13.3	1.11	0.90
	2	1.8	30.0	0.54	0.54 -
Kale	1	7.5	13.5	1.01	0.85
	2	1.8	31.7	0.57	0.57 -
Rape	1	7.3	20.7	0.97	0.79
	2	1.3	40.0	0.41	0.41 -
Sweet blue lupin	1	4.8	13.3	0.79	0.61
	2	1.6	31.7	0.48	0.48 -
Italian ryegrass	1	2.3	16.5	0.47	0.17
	2	1.0	30.0	0.40	0.40 -
H 1 ryegrass	1	3.0	19.5	0.58	0.27
	2	0.9	39.2	0.35	0.35

E.M. = Edible matter

D.M. = Dry matter

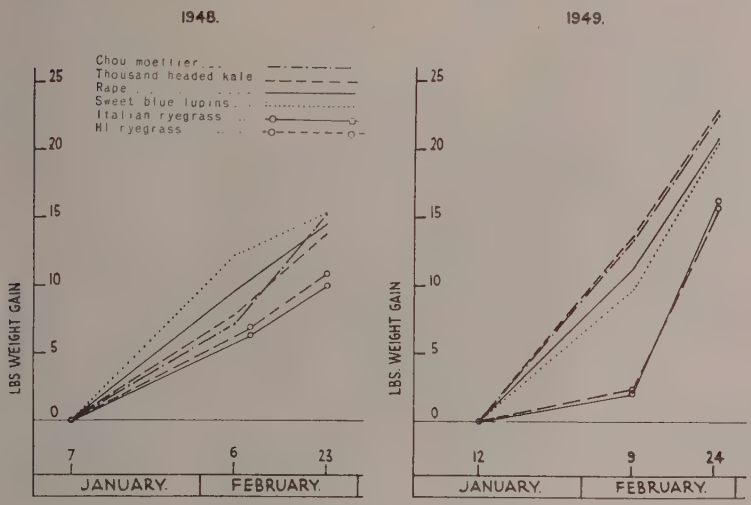

FIG. 2. Growth rates of lambs fed on various crops and pastures.

Results

Similar relative results were obtained each year. The brassicas and sweet blue lupin as a group produced weight-gains significantly greater than those from the ryegrasses, with no significant differences existing within the two classifications, although the consistent superiority of chou moellier and kale over rape and sweet blue lupin in 1949 approached significance, and possibly was a real result of feeding.

The estimate of total edible dry matter of all the feeds in 1949 show a pattern of values similar to weight-gains. The differences between the brassicas were not great, but on the first break they were far superior to the ryegrass, with lupin occupying an intermediate position. There appeared to be some correlation between weight-gain and dry-matter production per acre, but with the exception of the first breaks of ryegrass, production was well in excess of optimum requirements. The average calculated dry-matter consumption of similar lambs fattening on rape in previous years (Ewer, Bartrum and Sinclair; 1950) was approximately 1,000g per day. Taking this as an adequate amount, the total dry-matter requirement of any group would have been approximately 0·46 tons on the first break and 0·25 tons on the second, and thus the apparent correlation cannot be related to bulk of feed available. Estimated total dry-matter consumption shows that intake on the first breaks of ryegrass was below calculated requirements, and this is reflected in the poor performance of the lambs when grazing those breaks.

In general, the daily weight-gains on rape, sweet blue lupin, and ryegrass in 1948 were similar to those obtained in the past years, but in 1949, though over a shorter period, they were far greater than any achieved previously. The reason for this fact is not known, but it can be noted that the most vigorous growth occurred on the second break, and here, as shown in Table X, the dry-matter content of the feeds was very high, considerably higher than other figures recorded at Kirwee in previous years.

SECTION IV.—LAMB FATTENING ON PASTURE

Introduction

No attempt was made to fatten lambs on pasture until the autumn of 1945. This was due in part to a lack of improved pasture in the earlier years on the farm, but more to the fact that pasture, improved or not, produced no feed during the dry summers generally experienced. However, in 1945, when as previously mentioned the summer was unusually wet, pasture growth of all types was abundant. Associated with these atypical conditions, reports were received from many parts of Canterbury of lambs on pasture failing to thrive. Therefore, it was decided to investigate this condition by attempting to fatten typical unthrifty lambs upon the wide range of pasture types which

TABLE XI. FATTENING VALUE OF VARIOUS PASTURES
(Period 13 Mar. to 21 May - 69 days)

Group	Treatment and type of pasture	Hay eaten (lb)	Lambs per acre	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)
1	Old pasture mainly sub-clover; set grazing: Control.		1.66	43.1	15.9	0.23
2	Old pasture mainly sub-clover; rotational grazing + hay; drenched.	0.52	1.66	43.3	16.9	0.24
3	Red clover dominant pasture; set grazing.		5.0	43.4	16.8	0.24
4	Red clover dominant pasture; rotational grazing + hay; drenched	0.22	5.0	43.4	21.7	0.31
5	White clover dominant pasture; set grazing.		5.0	43.4	16.5	0.24
6	White clover dominant pasture; rotational grazing + hay; drenched.	0.28	5.0	43.3	21.8	0.31
7	Short Rotation ryegrass and clovers; set grazing.		5.5	43.3	18.7	0.27
8	Short Rotation ryegrass and clovers; rotational grazing + hay; drenched.	0.43	5.5	43.4	20.1	0.29
9	Perennial ryegrass and clovers; set grazing		5.5	43.3	17.5	0.25
10	Perennial ryegrass and clovers; rotational grazing + hay; drenched.	0.47	5.5	43.2	20.2	0.29
11	Red clover dominant pasture; set grazing		1.5	43.1	24.1	0.35
12	Lucerne; set grazing		2.0	43.0	20.3	0.29

Analysis of Variance of Groups 1 - 10

Source of Variation	df	ss	ms	F
Total	191	2910		
Between pastures	4	243	60.75	5.35 HS
Between systems	1	462	462	40.67 HS
Interaction	4	137	34.25	3.01 S
Within groups (error)	182	2068	11.36	

Significant difference between any pair of groups = 2.9 lb

was then available. Leading on from this experiment, a much reduced form of pasture fattening was repeated in the two succeeding years.

1945 Trial

Experimental Procedure

A single line of 270 Corriedale lambs in poor condition was purchased privately, and from it 12 groups of 20 lambs were selected and placed upon the range of pasture types at the rates of stocking and under the systems of management as set out in Table XI. In each case the rotation consisted of bi-weekly changes over a series of six breaks occupying half the same paddock as the set-grazed area.

Drenching consisted of an initial dose of 20g phenothiazine. Growth on all areas was abundant, and, irrespective of stocking, all lambs had more than sufficient feed available throughout the experiment.

As managerial and anthelminthic treatment were combined in this experiment, appropriate parasitological data have been included. Means of faecal egg-counts which were done on eight lambs in each group at 3–4-weekly intervals are presented in Table XI A as eggs per gram of faeces corrected for consistency, using methods previously described (Ewer and Sinclair; 1951).

TABLE XI A. NEMATODE PARASITE EGGS IN FAECES OF LAMBS FED ON VARIOUS PASTURES. (MEAN NUMBER PER GRAM)

Group	16 March	3 April	30 April	22 May
1	5860	1740	920	510
2	2510	650	220	100
3	2460	2200	2150	440
4	2780	1920	1410	180
5	2970	2160	1490	540
6	1850	920	360	310
7	5370	1570	1820	950
8	2320	940	1090	320
9	4300	2860	1690	820
10	3080	780	850	110
11	1580	1080	740	270
12	2150	1050	330	430

Results

Type of pasture: A group-to-group comparison showed that there were no significant differences in weight-gain between groups set-grazed on the various pastures at 5 lambs per acre, but that Group 11 grazed on red clover at the rate of 1·5 lambs per acre made a signifi-

cantly greater gain than either Group 1 on old subterranean clover at the same rate of stocking, or Group 3 on the same feed at the higher rate of stocking.

Management: An analysis of variance excluding Groups 11 and 12 and dividing the remainder into the two classifications of pasture type and feeding systems, shows a highly significant over-all difference between the systems, but the significance of the interaction term suggests that the effect of the rotation was significantly greater on the red and white clover pastures than on the ryegrasses. No reason for this was apparent, but the close duplication of the groups on clovers and the groups on ryegrasses, together with hay-consumption figures and mean egg-counts, suggests that an additional unknown factor associated with the rotation itself was responsible. The small hay consumption and the lower initial egg-counts of the groups on red and white clover confirm the belief that these factors were not involved.

The over-all reduction of faecal egg-count over the experimental period was 84·5 per cent among set-grazed lambs and 91·9 per cent among rotationally grazed lambs, which demonstrates that re-infestation with parasitic nematodes did not occur during the trial and thus it appears that a lower level of internal parasitism did not account for the superiority of the rotationally grazed lambs.

In spite of their poor initial condition, the lambs grew satisfactorily, the gain of 0·35 lb. per day made by Group 11 being better than anything obtained on rape and sweet blue lupin over a somewhat earlier period. The unthriftiness reported earlier did not develop, and, with the exception of five lambs in very poor condition which died early in the trial, no abnormal mortality occurred.

1946 Trial

This experiment involved three groups of 20 lambs which were similarly selected and fed concurrently with those on rape and sweet blue lupin. The treatments were based on the previous years' results in that it was planned to compare combined rotational grazing, hay supplement, and drenching with set-grazing on clover pasture, if possible, heavily contaminated with the infective larval stage of parasitic nematodes. For this purpose a vigorous clover pasture was selected and heavily grazed with ewes and lambs until December, while for further comparison a paddock of clover hay aftermath was kept free of stock in order to produce a relatively uncontaminated pasture.

Unfortunately, very dry summer conditions prevailed, and though the clover was fairly plentiful when the trial commenced, it dried off rapidly and towards the end little fed other than dry stalks was left. All groups were stocked at the rate of five lambs per acre, and the rotational system was the same as in 1945. The results are shown in Table XII and egg counts in Table XII A.

Results

The weather and pasture conditions were the extreme opposite of those in 1945, and, as a consequence, no further information as to the value of combined rotational grazing and drenching under conditions of good pasture growth was obtained. No doubt, as a result of the weather, egg counts showed a low level of worm infestation in all groups, and no significant difference in weight-gain developed between Groups 1 and 2 on "clean" and "contaminated" pasture respectively.

TABLE XII. 1946 TRIAL ON FATTENING VALUE OF VARIOUS GRAZING METHODS.
(Period 14 Jan. to 11 Mar. - 56 days)

Group	Treatment and type of pasture	Hay eaten per day (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)	Carcase weight (lb)
1	Clean pasture (clover hay aftermath); set grazing.		55.5	15.3	0.27	32.2
2	Contaminated clover pasture; set grazing		55.6	13.7	0.25	31.2
3	Contaminated clover pasture; rotational grazing + hay ad lib	1.29	55.2	10.1	0.18	32.8

Weight gain Error mean square = 11.28 lb
Significant difference between any two groups = 2.8 lb

TABLE XIIA. NEMATODE PARASITE EGGS IN LAMBS SUBJECTED TO VARIOUS GRAZING METHODS.
(Mean number per gram)

Group	16 Jan.	4 Feb.	22 Feb.	11 Mar.
1	100	870	520	520
2	180	180	500	220
3	370	140	480	300

The significantly poorer gain made by Group 3 was not confirmed by mean dressed carcase weight, which was in fact significantly higher in that group. This reversal of results suggests that an error was introduced into the final weighing which, it is thought, was related to high hay consumption of Group 3. The lambs were weighed finally on a Monday and Group 3 which was then consuming little less than 2 lb. of hay per lamb per day would have had no fresh ration exposed to them during the previous 48 hours. It was observed that over the latter part of the trial the lambs made the hay their main source of dry matter, they camped round the hay rack, and following a period of deprivation over the week-end they would have been relatively "empty" when weighed on Monday morning.

The gain of set-grazed lambs of 0·25–0·27 lb. per day was similar to that obtained in 1945, but did not compare with the concurrent gain of 0·40 lb. per day of lambs set-grazed on rape. No mortality occurred on pasture.

1947 Trial

Three groups of 30 lambs identical to those on rape and sweet blue lupin were selected. Two were used for a further repetition of the comparison of set- and rotational-grazing on clover pasture, and the third for testing the value of the mineral salt lick in comparison with the trial on rape and lupin.

A wet, early summer was experienced, and plentiful red-clover dominant pasture was available initially, but a spell without rain from 17 February to 21 March caused a considerable drying-off of feed as the experiment proceeded, although sufficient remained available until the end.

The same rotational system and stocking rate was practised as in the previous two years, but lambs were not drenched, as an initial

egg-count from 50 lambs gave a mean of 180 eggs per gram of faeces, which indicated that the level of worm infestation was well below that at which any response to drenching could be expected.

Results

The results are shown in Table XIII.

TABLE XIII. 1947 TRIAL ON FATTENING VALUE OF VARIOUS GRAZING METHODS
(Period 20 Jan. to 2 April - 72 days)

Group	Treatment and type of pasture	Hay eaten per day (lb)	Initial weight (lb)	Weight gain (lb)	Gain per day (lb)	Carcase weight (lb)
1	Red clover dominant pasture; set grazing.		55.0	17.9	0.25	33.6
2	Red clover dominant pasture; set grazing + mineral salt lick.		54.9	18.4	0.26	33.0
3	Clover dominant pasture + lucerne hay ad lib.	0.20	54.9	15.5	0.22	33.0

Weight gain Error mean square = 10.49 lb

Significant difference between any two groups = 2.2 lb

Although initially the clover pasture was similar, the results of 1945 were not repeated and Group 3, in fact, made smaller gains than Group 1.

The giving of a comprehensive mineral salt-lick to Group 2 brought about no significant increase in weight-gain.

The 0·25-lb. per day gain of set-grazed lambs was the same as in the previous two years, but again did not compare with 0·38 lb. per day concurrently obtained on rape. No mortality occurred during the experiment.

Summary of Section IV

Clover pastures with a wide variation of dry matter content from year to year consistently produced weight-gains in lambs of 0·25 lb. per day when stocked at the rate of five lambs per acre.

Under conditions associated with vigorous pasture growth and high initial parasite burden, a system of rotational grazing associated with a hay supplement and drenching with phenothiazine produced significantly greater gains on improved clover-dominant pasture, but not on ryegrass-dominant pasture. As this phenomenon was not repeated, no explanation is attempted. It appears, however, that a system of rotational grazing is of no benefit to lambs in dry weather when all active pasture growth has ceased and the feed is rapidly drying off.

DISCUSSION

Considered together, these lamb-fattening trials illustrate very clearly that lamb growth during the period under consideration was to a great extent dependent on factors beyond experimental control. For instance, lambs set-grazed on rape alone made weight-gains per day which varied from 0·16 lb. in 1942 to 0·47 lb. in 1949, an extreme range of 0·31 lb. per day, whereas the greatest positive result of any managerial treatment within an experiment was only 0·08 lb. per day.

Although the results were complicated by the higher than normal infestation with trichostrongylid nematodes in 1943 and 1945 (Ewer and Sinclair; 1951), which no doubt interfered with growth, it is apparent that there were large changes in the nutritional value of the feeds from year-to-year, or even from break-to-break within a year, which were dependent, to some extent, on the weather. The inability to control such variation together with the fact that no abnormal mortality occurred, largely defeated the object of these trials, which was to understand the nature of lamb mortality in Canterbury.

On this count the results obtained were generally of a negative nature, but as they were based on a quantitative assessment of the value of several common lamb-fattening practices, they may serve as a basis for recommendation against the use of those practices which were shown to be frequently uneconomical. The results are discussed under the general headings of the various feeding methods, supplements, and crops which were investigated.

The extent of the variation in rainfall over the summer and autumn months in the various years is shown in Table XIV.

TABLE XIV. RAINFALL 1940 - 1949
(Monthly Totals November - April)

Year	November	December	January	February	March	April
1939-40	1.78	4.09	3.31	1.64	0.84	--
1940-41	2.77	0.48	1.56	1.89	5.86	--
1941-42	1.59	1.91	2.31	2.07	2.43	--
1942-43	2.38	2.80	2.14	3.99	1.15	--
1943-44	0.96	0.76	0.75	4.34	2.45	--
1944-45	3.66	7.99	2.33	8.15	2.10	1.35
1945-46	0.37	5.45	1.58	1.20	1.48	--
1946-47	2.88	3.49	3.22	3.18	1.90	--
1947-48	0.82	0.94	2.27	2.52	--	--
1948-49	5.64	0.38	3.45	0.19	--	--

Feeding Methods

Set-grazing is taken as the control system of feeding with which all other methods are compared. As judged by individual lamb growth it was most consistently the best method of fattening, and certainly was the simplest and least time-consuming.

There was no evidence of any dangers being incurred by leaving lambs on rape when it was wet with rain or dew.

Break-grazing, using in the main a system of 7-day moves, brought about a small increase of weight-gain in two seasons, viz. 1943 and 1945, when high summer rainfall was experienced, but otherwise it was without effect in promoting better lamb growth.

Run-off to pasture: No benefit was derived from running lambs off green feed to old pasture. Almost invariably, a period on pasture either overnight or during the day depressed rate of growth, but did result

in some sparing of the green crop. Of what value this saving was could not be assessed under the experimental necessity of equal group size.

No doubt more lambs per acre could be carried when using a pasture run-off, but owing to slower growth the fattening period would, of necessity, be longer if first-grade export carcases are to be obtained. Considering the short grazing life of rape and sweet blue lupin under the uncertain summer rainfall in Canterbury, a long fattening period is fraught with risks. The grazing habits of lambs on fattening crops are not known, but their daily consumption of dry matter obviously must be limited by capacity or appetite, and the poorer growth of lambs run off to pasture may have been due to their total possible intake of dry matter from rape being partly replaced by the less nutritious dry matter from old pasture, or it may have been due to the mere factor of time. The longer the lambs were off the rape the less of it they ate.

Provision of Supplements

Except for the group of 1942 which was given an unlimited and uneconomical ration of subterranean clover hay of unusually good quality, hay and grain supplements were without effect in promoting better lamb growth. The theory behind the practice of giving hay supplements is that rape, usually classed as a succulent feed, is laxative and requires some supplement of roughage in order to maintain the proper function of ruminant digestion and thus to promote optimum growth. This theory was not substantiated at Kirwee. In dry periods the rape was mature and fibrous and extra roughage in the form of hay was not required by the lambs. In wetter periods the rape was soft, green and laxative, but also much more palatable, and consequently the lambs would not eat sufficient hay with it to increase appreciably the proportion of fibre in their total intake of feed.

It is worth noting that the lambs could not be persuaded to eat more than 0·4 lb. hay per day even when confined with their ration on a run-off overnight. It seems therefore that more drastic methods of curtailing their intake of green feed would have to be practised if the lambs were to be persuaded to eat sufficient hay to supply the theoretically necessary intake of roughage. Obviously such methods would defeat their own purpose of inducing rapid growth.

Effect of Mineral Deficiencies

There have been no authenticated reports of any trace element deficiencies on the light land of Canterbury, and three of the four years' investigation appeared to confirm that such deficiencies did not exist at Kirwee. No acceptable explanation can be offered for the highly significant positive response of the lambs on sweet blue lupin in 1947 to the lick containing the salts of their known mineral requirements. As this response could not be repeated the following year, it is assumed that it was related to the bought-in lambs used in 1947, and therefore not associated with any deficiency at Kirwee.

Crops

Sweet Blue Lupin

This crop gave substantially the same results as rape. Except for the unusual season of 1947, lamb growth on the two crops was closely

similar, and, although the initial bulk of feed was greater on sweet blue lupin, this fodder crop was unlike rape in that, when once fed off, it would produce no regrowth. Nevertheless, even if its feeding value and productivity has been shown to be no greater than rape, it undoubtedly has the additional advantage of being a useful soil improver on Canterbury's light land and of not being subject either to the earlier attack by the beetle (*Odontria zealandica*) or to the later attack by aphids, both of which not infrequently devastate rape crops.

The main disadvantage of sweet blue lupin is considered to have been the relatively restricted period during which it could be fed most profitably. At Kirwee, the lupin passed rapidly from maximum leafy growth through flowering to the formation of green seed-pods, at which stage it became stalky and distinctly less palatable to the lambs.

Chou Moellier and Thousand-headed Kale

These two feeds produced such similar results that they will be considered as one.

Although New Zealand Agricultural and Pastoral Statistics show that up to 20,000 acres of chou moellier and kale have been grown annually in Canterbury in recent years, there is no information regarding the purpose for which they were grown. In the writer's experience, however, they are seldom used or even recommended for fattening lambs. The reason for this is not understood, as the two years' trials in which chou moellier and kale were examined showed them to be the equal of rape and sweet blue lupin from a nutritional standpoint, and owing to their later maturity, possibly better in withstanding desiccation during dry periods.

Both trials were carried out either during or following very dry weather, and as such conditions are the most common in Canterbury, it appears that chou moellier or thousand-headed kale can be recommended with confidence as lamb-fattening feeds.

Pasture

The latter two sections of this paper show that either permanent improved pasture or temporary ryegrass leys did not compare with the fodder crops as lamb-fattening feeds, except for the case in 1945 when vigorous clover-dominant pasture was stocked at the uneconomical rate of 1·5 lambs per acre. Under both dry and wet summer conditions, smaller lamb weight-gains were obtained on pasture, and at a lower rate of stocking than that possible on the crops. It is not possible to arrive at a definite figure, but taking into account other lambs which were used to clean up the crop following experimental feeding, no less than 10 lambs per acre were fattened on the crops, whereas pasture could not withstand continuous grazing by more than 5 lambs per acre

Mortality

Excluding losses caused directly by experimental procedure, the average annual mortality of fattening lambs was 1·3 per cent, and as has been stated, this was caused largely by enterotoxaemia.

The wasting disease associated with heavy trichostrongylid infestation, the investigation of which was the primary aim of these experi-

ments, was not apparent throughout the ten years' observations, except for a brief period early in 1943. In other words, it would appear that only rarely does this disorder become of serious importance in Canterbury.

The figure of 1·3 per cent is considered to be well within normal limits, although no other figures for Canterbury or other parts of New Zealand are anywhere recorded. The small but regular loss through enterotoxaemia was accepted as unavoidable, as it was not large enough to warrant preventive vaccination.

Acknowledgment

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THE ESTIMATION OF CAROTENE IN PLANT MATERIAL AND FAECES*

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Summary

A method, based on a cold ethanol-petroleum ether extraction followed by chromatography on a column of Hyflo Super-Cel, has been suggested for the estimation of carotene in plant and related materials. The method, which introduces a number of modifications to published procedures, is simple and rapid, and is suitable for the routine assay of large numbers of samples. It has been used for the estimation of carotene in fresh and dried herbage, ingesta samples and faeces, and has given results in good agreement with those obtained by other commonly used methods. The accuracy and reproducibiltiy of the method has been extensively investigated.

Introduction

A large number of methods for the estimation of carotene in plant and related materials have been described over the last few years. Although widely differing techniques are employed, the methods for extracting the pigments fall in general into two main groups: those requiring a preliminary saponification and those in which this step is omitted or follows extraction of the pigment with organic solvents. Direct extraction, using solvents such as acetone, methanol, ethanol, pyridine, di-acetonol, petroleum ether, and mixtures and combinations of these, has been effected at room temperature by slow maceration, or more rapidly by grinding the material with the solvent or by the use of a Blendor, while other workers have preferred hot extraction in apparatus of the Soxhlet type. A number of these methods together with errors inherent in certain of them, have been reviewed and discussed by Booth.[1]

A recent investigation in this Department necessitated estimating carotene in a range of materials such as hays, fresh and dried grasses, ingesta and dung, and published methods were considered with a view to obtaining a rapid but accurate method readily applicable to all of these materials.

Carotene is readily isomerised or oxidised by heat[2, 3] so that errors might be expected from methods involving hot solvents, or concentration by heat of carotene solutions. Zeichmeister[4] has reported 10 per cent isomerisation of carotene on refluxing a solution in petroleum ether for 15 to 60 minutes. It seemed reasonable to assume that methods involving saponification with hot alkali might introduce the same errors. In addition, several workers have reported destruction of carotene by hot alkali,[5, 6] and Lease and Mitchell[7], and Fraps and others[8] have found that alkali isomerises the carbohydrates in certain materials to form a resinous film which renders the carotene non-extractable by organic solvents. Dried materials and faeces present special difficulties due to the possible presence of oxidation products of the carotenoids which may give rise during extraction to artifacts

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absorbing in the region of the carotene maximum. Thus Ramasarma and Hakin[9] found a yellow epiphasic pigment in the faeces of rats fed a carotene-free diet; Whitnah and others[10] found with cows an apparent excretion of over 100 per cent of ingested carotene, as estimated by distribution between petroleum ether and aqueous methanol; Quackenbush and others[11] reported that similar pigments developed in A.I.V. silage, but Hegsted and others[12] were able to remove these by replacing the methanol with di-acetonol; Hartman and others[13] noted the differences between biological values and chemical values (obtained by phasic separation methods) for the potency of lucerne hay, and subsequent workers[14] showed the presence of 11–32 per cent of non-carotene pigments in the petroleum-ether layer.

Selection of Methods

From a consideration of the available methods for plant materials and the criticisms of these, it appeared that the cold solvent methods such as those described by Wall and Kelley[15], and Moore and Ely[16], for extracting the pigments, followed by separation on a column of Hyflo Super-Cel as suggested by Wilkes, [17] were most readily applicable to the range of samples to be handled, and least subject to the foregoing sources or error. However, the Association of Vitamin Chemists in a recent publication[18] recommends, in addition to the method of Moore and Ely,[16] a saponification method and the Soxhlet extraction method also described by Wall and Kelley[15]; during the course of the present investigation, Derby and DeWitt[19] reported a comparison of the Wall and Kelley cold extraction method with their modified A.O.A.C. method, and with a method involving digestion with alocolic potash. Although the Association of Vitamin Chemists points out the possibility of isomerisation of carotene in the Soxhlet method, Derby and DeWitt obtained the highest results with their modified A.O.A.C. method which also involves the use of hot solvents. Methods of extraction, using cold solvents in the Waring Blendor, were therefore compared with the A.O.A.C. method as modified by Derby and DeWitt. Although alkali digestion has been so strongly criticised, it does offer a convenient method of disrupting the tissues and allowing the solvent to come into more intimate contact with the pigments, and it seems possible that the errors attributed to it might be due to the somewhat drastic conditions usually employed both as regards duration of heating and strength of alkali. A digestion method using mild conditions was therefore investigated. In addition, preliminary work had suggested that a number of the steps in standard methods could be eliminated without loss of accuracy, and a method based on that of Moore and Ely[16] and introducing these modifications was also investigated.

Experimental Procedure

Representative samples of the types of material to be investigated were assayed by the following methods:

Method 1: The A.O.A.C. method[20] as modified by Derby and DeWitt[19] except that the extraction was carried out in a Soxhlet apparatus in place of the Bailey-Walker extractor, which was not available.

Method 2: The method of extraction in a Blendor using a "foaming mixture" of petroleum ether and ethanol as described by Moore and Ely.[16]

Method 3: In this method, which is an adaptation of the previous one, and in *Method 4,* two modifications to standard procedures were introduced:

(a) During the initial extractions definite volumes of solvents were used and precautions were taken to prevent loss by evaporation. Aliquots of the solutions were then taken, so avoiding the necessity for repeated washings or re-extractions of the marc.

(b) Repeated extractions of the alcoholic solution of the pigments with petroleum ether to remove all the carotene were avoided by adding water equal to the volume of ethanol present, and extracting with twice this volume of petroleum ether. It had already been shown that under these conditions the one extraction with ether removes all the carotene, and that the two layers separate sharply with no volume change. These preliminary experiments which are supported by the carotene recovery figures cited below also showed that other materials present did not affect the distribution, and that the method was equally applicable to plant extracts. More of the non-carotene pigments may be removed by a higher concentration of alcohol in the hydrophase, but with concentrations greater than about 60 per cent, it was found that some carotene was retained and re-extraction with further petroleum ether was necessary. Further, 50 per cent alcohol gives the sharpest separations of layers without volume changes.

Up to 10 g of the material, depending on the carotene content, was comminuted in a sealed jar on the Waring Blendor for 5 minutes with 100–200 ml of a foaming mixture consisting of a 25–35 per cent solution of petroleum ether in 95 per cent ethanol. Dried samples were first moistened with a small quanity of water, as the foaming mixture does not completely extract dry materials. After comminution, the residue was allowed to settle, an aliquot of the supernatant liquid withdrawn, and water and petroleum ether added to give approximately equal volumes of ether and 50 per cent ethanol.

The ether : alcohol ratio required to give a foaming mixture depends on the moisture content of the sample. Since an aliquot of the solution is to be taken later, the estimation is simplified if there is a definite volume of water present. For most materials it was found convenient to add to the weighed sample in the Blendor jar, sufficient water to bring the total amount of water present (including the moisture originally in the sample) to 5 ml. This moist mass was then extracted with 135 ml of a foaming mixture containing 26 per cent petroleum ether (100 ml ethanol and 35 ml ether). In this case the total volume of extractant is 140 ml and 40 ml forms a convenient aliquot containing 10 ml ether, 28·6 ml ethanol and 1·4 ml water. To give the correct ratios of ether, ethanol and water, this requires the addition of a further 47·2 ml petroleum ether and 27·2 ml water. There is, however, some latitude in the ratios, and it is more convenient to add 50 ml ether and about 25 ml water, the carotene in the original sample now being contained in the equivalent of 210 ml petroleum ether.

Where the moisture content of the sample itself exceeds 5 g, the 100 ml 95 per cent ethanol is replaced by 95 ml absolute alcohol, and the moisture content adjusted to 10 ml by the addition of water to give the same total volume of 140 ml. After addition of the ether and water, the two phases were shaken vigorously, and after standing for a few seconds the bottom layer was discarded. Prior to chromatography, a portion of the petroleum-ether solution was washed twice by shaking gently with several times its own volume of water to remove traces of ethanol.

Method 4: Up to 5 g of the sample were digested by refluxing for 10 minutes with 50 ml ethanol and 5 ml 50 per cent potassium hydroxide. The solution was cooled rapidly and poured through a pad of glass wool. To an aliquot consisting of half the total volume, i.e. 27·5 ml plus half the volume of water in the sample, 50 ml petroleum ether was added, followed by 20 ml water. Using these volumes the carotene present in the sample is contained in 100 ml petroleum ether, and a portion of this solution was washed with water as in Method 3.

The washed petroleum ether solutions of the pigments obtained by these four methods were dried over anhydrous sodium sulphate. In each case 20–30 ml aliquots of these solutions were chromatographed on lightly packed Hyflo Super-Cel columns using the apparatus illustrated in Fig. 1. Petroleum ether was then drawn through the column until colourless washings were obtained. With the particular columns in use, about 20 ml ether was adequate for the complete removal of carotene. Several extracts could normally be run through the one column, but, with some samples, a yellow artifact moved down the column fairly rapidly behind the carotene, and in these cases it was necessary to elute all the pigments after each determination. This was most conveniently carried out by running through 20–30 ml ethyl ether. After washing with an equal volume of petroleum ether and drawing dry of solvent, the columns were again ready for use.

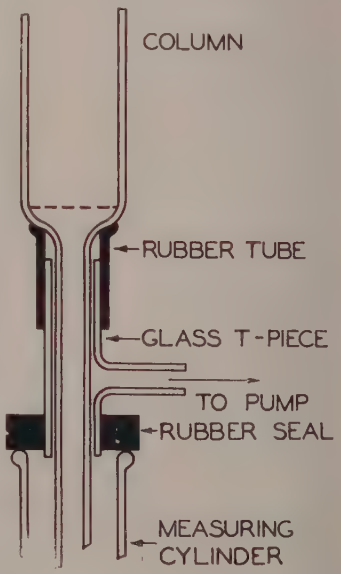

Fig. 1

In all cases, carotene was estimated in petroleum ether solution using a Beckman Model D.U. Photoelectric Spectrophotometer set at 450 mμ with a nominal band width of 0·5 mμ.

Results

The carotene content of a number of samples as determined by these four methods is shown in Table I. The results represent the average of at least three determinations. Carotene losses in Methods 3 and 4 were checked by the addition of known amounts of carotene. Recoveries are listed in Table II and III.

TABLE I.

Carotene contents of various samples expressed in ug/g dry matter

Material	Carotene Content recorded			
	Method 1	Method 2	Method 3	Method 4
Fresh grass	-	718	708	682
Dried grass 1	-	-	352	334
" " 2	356	340	345	322
Faeces (Sheep) 1	-	42.4	41.5	43.2
" " 2	-	-	22.0	21.5
Hay 1	23.4	23.1	23.3	22.8
" 2	15.9	15.2	15.7	14.4
" 3	18.8	-	19.1	19.0
" 4	-	-	14.8	14.4
Ratios %	100	99	99	96

TABLE II.

Carotene recoveries using Method 3

Material	Carotene in sample (ug)	Carotene added (ug)	Total Carotene (ug)	Carotene found (ug)	Recovery (%)
Dried Grass 1	352	97	449	438	98
" " 1	352	194	546	538	98
" " 1	352	291	643	648	100
" " 1	352	388	740	728	98
Hay 4	74.0	18.2	92.2	93.1	101
" 4	74.0	36.4	110.4	108.8	98.5
" 4	74.0	91.0	165	169	102
-	-	194	194	192	99
-	-	291	291	290	100
-	-	388	388	391	101
Average Recovery					99.5

TABLE III.

Carotene recoveries using Method 4

Material	Carotene in sample (ug)	Carotene added (ug)	Total Carotene (ug)	Carotene found (ug)	Recovery (%)
Hay 4	72.0	22.4	94.4	91.2	96.5
" 4	72.0	44.8	116.8	116.0	99
" 4	72.0	112.0	184	177	96
" 4	72.0	224	296	280	95
Dried grass 1	334	224	558	525	94
" " 1	334	112	446	436	98
Average Recovery					96.5

Table I shows that contrary to the findings of Derby and DeWitt,[19] who worked only with dehydrated alfalfa meal, the results obtained by the four methods agreed closely in this investigation. Method 4 does tend, however, to give slightly lower and less reproducible results, and the low recoveries by this method (Table III) indicate destruction of carotene by the hot alkali in the presence of other plant material, although on its own carotene is not destroyed to any appreciable extent by similar treatment. Apart from the possible sources of error mentioned already, Method 1 is not applicable to fresh materials or faeces without preliminary drying, and since it does not appear to extract carotene any more completely than the other methods, it was not investigated further. Method 3 possesses the advantages of speed and simplicity, and appeared applicable to the routine estimation of carotene in a wide range of materials. The method gave consistent results; typical figures in micrograms per gram dry matter for the mean of six determinations on a number of samples were: hay 3, 19·1 ± 0·4 (2 per cent); dried grass 1, 352 ± 10 (3 per cent); and fresh grass 708 ± 35 (5 per cent.). (The larger deviation in the latter case could probably be attributed to sampling errors.)

A further check on the completeness of extraction of carotene by this method was obtained by re-extracting the residues from a number of extractions. These combined residues were washed on a sintered glass filter with "foaming mixture" until the filtrate was colourless and re-extracted both on the Blendor with fresh foaming mixture and in a Soxhlet apparatus by Method 1. In many cases any further carotene extracted was too small to be measured, and in no case did it exceed 2 per cent of the amount estimated on the first extraction. Typical examples are shown in Table IV.

Although the 26 per cent foaming mixture was found to be satisfactory for most samples, it may be necessary to vary its composition in certain cases. The effect of such variations was investigated by extracting a sample of hay (estimated without addition of water) with different ethanol-petroleum-ether mixtures. The results in Table V indicate that over a wide concentration range the efficiency of extraction is unaltered.

To check the completeness of separation of other pigments from carotene on the Hyflo Super-Cel column, this adsorbent was compared with other more commonly used materials. Petroleum ether solutions of the pigments obtained by Method 3 were run through columns of di-calcium phosphate, bone meal, and 3 : 1 mixture of Hyflo Super-cel and magnesium oxide prepared and used as described by Moore,[21] Mann,[22] and Wall and Kelley[15] respectively. Phasic separation was also compared with the Hyflo column.

Aliquots of the ether solutions obtained by Method 4 were repeatedly shaken with equal volumes of 90 per cent methanol (90 ml methanol plus 10 ml water), until the hydrophase was colourless. As has been reported by a number of workers, the adsorbents tested gave almost identical results with quantitative recoveries of carotene. The rate of flow is, however, most rapid with Hyflo Super-cel, and this adsorbent appears to be one of the few which fulfil the requirements for routine assays, being simple to use and less variable than the other materials. A comparison of phasic separation with adsorption on a column of Hyflo is shown in Table VI. It is apparent that,

TABLE IV.

Completeness of extraction by Method 3

Material	Carotene by first extraction (ug/g)	Re-extracted by			
		Method 3 (ug/g)	(%)	Method 1 (ug/g)	(%)
Hay 3	19.1	0.22	1.5	0.18	1.0
" 4	14.8	0.1	1	0.12	1.0
Dried grass 1	352	15	0.5	10	0.5
Faeces 1	41.5	0.59	1.5	-	-

TABLE V.

Effect of varying the concentration of the foaming mixture. (5 g Hay 3 extracted dry with 150 ml foaming mixture of various concentrations.)

Concentration of petroleum ether in mixture	Carotene found (ug/g)
25	18.7
30	19.2
35	18.8
40	18.7
45	19.1
50	18.8
Average	18.9

TABLE VI.

Separation of carotene from other pigments by distribution between immiscible solvents compared with chromatographic separation on a column of Hyflo Super-Cel.

Material	Apparent carotene in ug/g as estimated by -		
	Phasic Separation	Hyflo Super-Cel	Phasic separation followed by Hyflo Super-Cel
Hay 2	15.8	14.4	14.4
" 3	19.6	19.0	19.1
Dried grass 2	328	322	330
Faeces 1	47.5	43.2	42.8
Fresh grass 1	675	683	672
" " 2	485	478	482
" " 3	380	385	380

as was expected, much of the material under consideration contained epiphasic non-carotene pigments which invalidate the results obtained from phasic separation, and this relatively simple method was not therefore applicable. For fresh samples, however, it is probably as

accurate as adsorption methods. When distributed between petroleum ether and 90 per cent methanol, the non-carotene pigments normally encountered were found to have a distribution coefficient of about 9 to 1 in favour of the hydrophase. To avoid repeated washings it is necessary to use a large volume of methanol, and it was found that if the ether layer is washed with an equal volume of 90 per cent methanol, saturated with petroleum ether, no volume changes occur, and no carotene passes into the hydrophase. Two such washings reduce the non-carotene pigment in the epiphase to about 1 per cent. of the original level.

Conclusions

It is apparent that with the materials investigated, the four methods gave results in reasonably close agreement, although with the saponification method some loss of carotene occurred, as indicated by the low recoveries of added carotene. The other three methods gave almost identical results. Methods such as that of Moore and Ely[16] seem most readily applicable to the routine analysis of materials of the widely differing types under consideration. Only a few minutes is required for the complete extraction of the pigments with the cold solvent in the Blendor, thus facilitating the rapid handling of large numbers of samples with a minimum of apparatus. Further, from the results obtained with Method 3, it is apparent that, without loss of accuracy, the time required for each assay may be considerably reduced. This is achieved by the taking of aliquot samples after the initial extraction thus avoiding repeated washing or re-extraction of the marc, and by transferring the carotene quantitatively to petroleum ether in one extraction, using suitably adjusted volumes of ethanol, water and petroleum ether. Combining this method of extraction with adsorption on a column of Hyflo Super-Cel gives a rapid, convenient method which, it is considered, will be applicable to the assay of carotene in plant and related materials.

Acknowledgments

The author desires to express to Dr. C. R. Barnicoat and Mr. R. W. Cawley, of the Biochemistry Department, Massey Agricultural College, his appreciation for the interest shown by them in this investigation. The work has been financed by University Research Grants and carried out during the tenure of a University Research Fellowship.

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DETERIORATION OF SOIL STRUCTURE IN A SOUTH CANTERBURY SOIL

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Summary

Chemical and physical analyses were made of the soil from two fields of a South Canterbury farm in which there had been recent crop failure.

Chemical analysis showed the soils to be low in exchangeable potassium, and much lower in organic matter than the soil of an adjacent uncultivated headland.

Physical measurements related to: (1) Water-stable aggregate analyses by wet sieving; (2) stability of aggregates to wetting; (3) porosity measurements; (4) division of the total porosity into large and small pores.

By all these methods of measurement both fields were found to be in a poorer physical state than the uncultivated headland. These findings would suggest that a marked deterioration in soil structure had occurred as a result of an unsuitable crop rotation system.

Ploughing was found to increase the total porosity and volume of large pores, but this effect was thought to be of only short duration, since the poor stability of the soil aggregates was not improved by such treatment.

With a one-year-old pasture where limed and unlimed strips of the field were available for sampling, liming showed no improvement of soil structure.

Introduction

On first-class Canterbury soils good cropping practice is considered to be two successive crops of wheat, or, alternatively, one crop of wheat followed by some other grain. The land is next sown down to green feed and grass, which is left for four years. Following the grass, turnips and rape are sown in succession. This completes the rotation, and wheat is then sown again. On second-class land only one crop of grain is taken in the rotation. Some farmers crop to wheat more frequently, with the result that yields decline. One of the writers (J. D. R.) visited a farm on second-class land where wheat had been sown every second year for a number of years, producing in later years very small harvests. This farm presented an excellent opportunity to measure the chemical and physical changes that had taken place in the soil under these conditions.

The investigation was commenced in 1944, but although some water-stable aggregate analyses showed that structure deterioration was present, the physical methods then used for examining the pore-space relationships of the soil failed to give satisfactory results. This latter aspect of the problem was deferred until 1948 when a fresh attack was made by methods which had been developed satisfactorily overseas in the meantime. The chemical examination of the soils, however, was concluded in 1944. When the investigation was re-opened in 1948, more careful water-stable aggregate tests were made, and the results of these are reported here.

Description of Soil and Fields

The farm is located on the South Canterbury Plains near the eastern margin of the downland on the Claremont silt-loam soil type,

a yellow-grey earth. The soil closely resembles that of the extensive eastern downs to which it is adjacent; it developed under the same climate and vegetation, was derived from the same parent material of the same age, and differs only in that it is on flat topography. The rainfall is 25 in. a year. The profile is:

6 in. to 7 in. grey silt loam with moderate crumb structure.
6 in. light grey to yellow-grey silt loam, with soft crumb structure, some concretions and some orange and rusty mottling.
7 in. to 11 in. yellow-brown heavy silt loam somewhat more compact with much orange and rusty flecking.
on darker yellow-brown heavy silt loam to silty clay loam, moderately compact to compact.

Two fields were chosen for investigation and these are referred to as Field 1 and Field 2. For comparison with the cropped fields it was considered desirable to obtain samples from a piece of land which would represent the soil in its virgin state. As such land was not available, an uncultivated corner of Field 1, separated from the remainder of the field by a dry watercourse and therefore inaccessible to tillage implements, was chosen as the nearest approach to an undisturbed soil. This patch of uncultivated land is referred to as a headland of Field 1. Samples of cultivated soil were taken from Fields 1 and 2.

When samples were taken in 1944 by one of the authors (J. D. R.) the following observations were recorded about the fields:

Both fields have been top-dressed with superphosphate at infrequent and irregular intervals during the past twenty years, but the total dressing over the period is estimated to be less than 5 cwt. per acre, having been applied at a rate of less than $\frac{1}{4}$ cwt. an acre annually. No lime has been added to either field.

Field 2 has been sown in wheat every second year for at least the past twenty years. In the intervening years it mostly lay fallow. In 1944, a pea crop grown on this field was a total failure. Field 1 was also heavily cropped, probably to about the same extent, but exact records are not available. A linen flax crop grown in 1943 failed to reach the necessary standard for acceptance.

In both fields the uncultivated soil can easily be distinguished from the cultivated soil by its colour, the former being dark grey and the latter pale bleached grey. The uncultivated soil has a moderately good crumb structure; the cultivated soil has the feel and general appearance of a recently deposited river silt. When wet, the uncultivated soil remains firm; the cultivated fields waterlogged easily, and in wet weather resemble quagmires in which one sinks to the ankle. Both the fields are now difficult to cultivate. In spring, they are late in drying out sufficiently to carry implements, and when ploughed the soil either forms large wet lumps with an excessive draught, or if dry, readily powders to dust. In mid-summer, crops wilt sooner than the grass in the headlands. The cultivated soils have somewhat more compact subsoils than the headland soils, and there is also a noticeable difference between the smell of the uncultivated and the cultivated topsoils, the former having the characteristic earthy smell of a good garden soil, whilst the latter have a stagnant smell.

When the farm was visited again in 1948, Field 1 was still being cropped to wheat; in February of that year, when samples were taken, the field had only recently been ploughed; it was later sown down to wheat. Field 2 was no longer being cropped in 1948, but was carrying a one-year-old pasture. Prior to sowing down to grass, the farmer had, as an experiment, limed strips of this field and left other strips unlimed; samples for physical analysis were taken from both treated and untreated strips.

A record of all samples taken is contained in Table I. All samples were from the 0–6 in. layer of soil.

TABLE I. RECORD OF SAMPLES TAKEN

Sample No.	Time of Sampling	Field Sampled	Description of Field	Purpose of Sampling
3292 3425 3428 3436 3437	July 1944 Oct. " " " " " " "	Headland of No. 1	Uncultivated	For chemical analysis.
3293 3294 3424	July 1944 " " Oct. "	No. 1	Linen flax crop rejected in 1943	For chemical analysis.
3295 3426 3427	July 1944 Oct. " " "	No. 2	Pea crop complete failure in 1944	For chemical analysis.
S59 S60 S61	Feb. 1948 " " " "	Headland of No. 1	Uncultivated	Can samples for porosity and moisture characteristics measurements.
S56 S57 S58	Feb. 1948 " " " "	No. 1	Recently ploughed	Ditto.
S62 S63 S64	Feb. 1948 " " " "	No. 2	Carrying one year old pasture. Limed strip.	Ditto.
S65 S66 S67	Feb. 1948 " " " "	No. 2	Carrying one year old pasture. Unlimed strip.	Ditto
S126	Aug. 1948	Headland of No. 1	From same site as S59-S61	Clod sample for aggregate analysis.
S127	Aug. 1948	No. 1	From same site as S56-S58	Ditto.
S128	Aug. 1948	No. 2	From same site as S62-S64	Ditto.
S129	Aug. 1948	No. 2	From same site as S65-S67	Ditto.

EXPERIMENTAL METHODS

Chemical Examination of the Soils

The methods of chemical analysis were those normally employed by the Soil Bureau of New Zealand. Organic carbon was determined by the chromic acid reduction method of Allison, and total nitrogen by the micro kjeldahl method. pH was measured on a quinhydrone electrode using a soil : water ratio of 1 : 2·5. Base exchange determinations were done by leaching with normal ammonium acetate at pH 7. Available phosphate was measured by extracting with 1 per cent citric acid.

TABLE II. CHEMICAL ANALYSES

Field	Number of samples averaged	pH	Available P_2O_5 (%)	Organic C (%)	Total N (%)	C/N	Base Exchange					
							Exchange capacity (m.e.%)	Total Bases (m.e.%)	Base Saturation (%)	Ca (m.e.%)	Mg (m.e.%)	K (m.e.%)
Headland of No.1	5	5.2	0.013	4.2	0.32	13	15.2	4.4	28	2.8	1.7	0.3
No. 1	3	5.4	0.018	2.7	0.22	12	13.9	3.8	27	3.0	1.0	0.3
No. 2	3	5.3	0.017	2.3	0.17	14	12.1	3.3	27	2.3	0.9	0.2

The results of the chemical analyses are set out in Table II. Several determinations were made for each soil, corresponding to the sample numbers 3292 to 3427 listed in Table I, but only averages for the three different soils are given in Table II.

All the soils were found to be moderately acid, the variations between samples from the cultivated fields and the headland being small. The phosphate figures showed small increases in the cropped areas, apparently due to the top-dressings of superphosphate. The base exchange figures did not vary greatly, although the capacities in the uncropped soils were higher than the others because of the greater amount of organic matter present. The percentage base saturations, however, remained closely similar. Both cultivated and uncultivated soils were low in exchangeable potassium, and this may have contributed to the poor regenerative power of the soil, since clover growth, and hence grass, would be affected. The most significant differences between the headland and cropped fields are found in the figures for carbon and nitrogen. It appears that approximately 40 per cent of the humus has been lost from the cultivated soils; this would probably have a deteriorating effect on soil structure.

Examination of the Structure of the Soils

The physical examination of the soils was carried out to find what differences might exist between the structure of the headland soil, representing the soil in its uncropped condition, and the soils of the heavily cropped fields. Four sets of measurements designed to show structure changes were made:

(i) Water-stable aggregate analyses;
(ii) Stability of aggregates to wetting;
(iii) Total porosities of the soils;
(iv) Division of total porosity into large and small pores.

(i) Water-stable aggregate analyses were made by wet sieving, using an adaptation of the method described Bouyoucos.[1]

Bouyoucos used a single unbroken clod of air-dry soil, but owing chiefly to the fact that the samples to be tested in this investigation contained quantities of fine plant roots which obstructed the complete separation of the larger aggregates from each other, it became necessary to alter Bouyoucos's pretreatment in order to obtain reasonably reproducible results. The pre-treatment finally adopted was the following:

A sample of 50 g. air-dry soil, consisting where possible of a single clod, was broken gently by hand into fragments about the size of plum stones, and oven-dried at 105°c. After cooling and weighing, the soil was soaked in distilled water for 15 minutes before being transferred with approximately 400 ml. distilled water to a quart bottle to be shaken in an end-over-end shaker for 5 minutes. The contents of the bottle were then subjected to the sieving analysis by hand as described by Bouyoucos.

In addition to the sieving, a determination of the silt-plus-clay in the undispersed suspension which passed through the last sieve was made by taking a pipette sample as for mechanical analysis. For the purpose of deriving the particle diameter in this determination, the particles were assumed to have a density equal to that of the dispersed particles,

The process of oven drying the soil before wet sieving is contrary to the recommendation of Yoder[2], but has given more consistent results than were obtained for air-dry soils. Shaking the aggregates in water before sieving follows the recommendation of Baver and Rhoades[3] who, however, used a reciprocating shaker.

(ii) The stability of the aggregates to wetting was examined by the "moisture characteristic" method of Childs[4, 5] as modified by Feng and Browning[6].

The term "moisture characteristic" or more fully "soil moisture characteristic curve" was introduced by Childs to denote the curve showing the relationship between the moisture content of a soil sample and the pressure deficiency with which it is in equilibrium. Using the buchner funnel method of Haines[7] to obtain moisture characteristics for a range of pressure deficiencies from zero up to about 50 cm. water, Childs showed that these curves, if obtained for a selected range of aggregates passing a 2-mm. sieve but retained on a 1-mm. sieve, could be analysed to give information about the stability of the aggregates. Feng and Browning, following on Childs' work, proposed a "stability factor" deduced from the analysis of the moisture characteristics for sieved samples, and claimed that it gave a better measure of the stability of the aggregates than the factor tentatively put forward by Childs.

In the present investigation, the stability factor of Feng and Browning was adopted. Samples for determining the moisture characteristics of a selected range of aggregates by the Haines buchner funnel method were prepared as follows:

A sample of aggregates passing a 2-mm. sieve but retained on a 1-mm. sieve was obtained by lightly crumbling the air-dry soil in the hands, and then sieving. A weight of about 20 g. of the sample was allowed to moisten by placing it on a filter paper which had a projecting portion dipping into a dish of water. This wetting by capillarity was performed to prevent any undue breakdown of the aggregates by slaking, which might otherwise have occurred when the dry sample was rapidly wetted in the buchner funnel apparatus.

(iii) The total porosities of the soils were measured by taking core samples and obtaining their volume-weights in the usual way. The particle densities for the soils were later obtained by the density-bottle method using toluene as the displacing liquid; this completed the data necessary for the calculation of the total porosities. The sample size was approximately 4 in. diameter by 3 in. deep.

(iv) An indication of the distribution of pore space was gained by taking measurements to show the division of the total pore space into large and small pores, in other words, finding the so-called non-capillary and capillary porosities. Leamer and Shaw[8] interpreted the non-capillary porosity as the volume of pores drained when the pressure deficiency of the sample was increased from zero (saturation of sample) to a fixed and predetermined value. Nelson and Baver[9], basing their conclusions on observations of the permeability at the flex point of the pH curve, suggested a value of 40 cm. water ($pF = 1{\cdot}6$) as the "logical" value of pressure deficiency to use in determining non-capillary porosity. The danger of attempting too rigid an interpretation of non-capillary porosity was stressed by Childs, but in view of the obvious usefulness of the concept of a division of porosity into large

and small pores, it was decided to make such measurements. However, in order to emphasize the essentially arbitrary choice of a dividing line it was decided not to use the expressions "capillary" and "non-capillary" porosity, but substitute "volume of small pores" and "volume of large pores" instead. This is in line with a suggestion of M. B. Russell[10].

The measurements were made in a buchner funnel apparatus in a manner very similar to that used in finding the moisture characteristics of the sieved aggregates. Samples were obtained from the core samples used for the total porosity measurements. After the total porosity had been found, the cans were placed without lids in a tank

TABLE III. WET SIEVING ANALYSES

Particle size (mm)	Samples examined							
	S126		S127		S128		S129	
	Aggregates (%)	Standard error	Aggregates (%)	Standard error	Aggregates (%)	Standard error	Aggregates (%)	Standard error
>2	32.5	5.1	3.6	0.41	1.9	0.27	2.1	0.30
2 - .84	9.6	0.59	7.4	0.53	4.8	0.27	6.1	0.50
.84 - .42	8.3	0.87	18.2	1.00	17.2	0.29	17.6	0.51
.42 - .25	3.1	0.24	7.9	0.29	9.2	0.32	9.1	0.27
.25 - .18	2.5	0.28	5.0	0.25	6.8	0.38	6.2	0.24
.18 - .15	2.0	0.19	2.8	0.18	3.9	0.10	2.8	0.06
.15 - .02	27.4	2.5	32.9	0.82	33.7	0.19	33.7	0.73
<.02	11.9	1.3	19.8	0.35	20.2	0.41	20.3	0.40
Moisture content	2.7	0.03	2.4	0.02	2.3	0.07	2.1	0.08

of water, the surface of which reached just below the top of the cans, and the soil allowed to saturate overnight. Suitable sub-samples, cut from the saturated core samples with a small sampling cylinder, were obtained, quickly transferred to a buchner funnel apparatus, and pressed gently but firmly on to the filter-paper membrane to make good contact. The volume of the large pores was taken to be the percentage of the total apparent volume of the sample which was drained when the pressure deficiency was increased from zero to 40 cm. water.

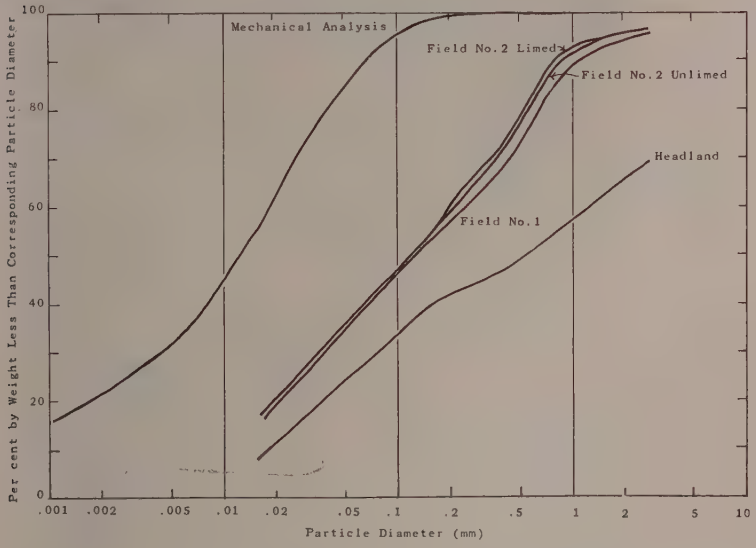

Fig. 1. Aggregate Analysis Summation Curves

Results

Water-stable Aggregate Analyses

The results for each sample (Table III) are the mean of five replicates, and the standard errors of the means are given.

The figures from Table III have been plotted in the form of summation curves with a logarithmic scale for particle diameters, and are shown in Fig. 1. For comparison, Fig. 1 also shows a mechanical analysis curve which is the same for all the samples collected. This mechanical analysis of the soil shows the particle sizes to be:

Coarse sand, 1 per cent; silt, 41 per cent;
Fine sand, 36 per cent; clay, 22 per cent.

In trying to compress the data from an aggregate analysis into a single figure to represent each soil, it has been common to quote the degree of aggregation [11, 12] at a given minimum aggregate diameter, d. This may be defined as the proportion of mechanical separates with a diameter smaller than d which are to be found in aggregated particles with a diameter larger than d. Thus if the percentage of particles smaller than d as found by mechanical analysis is A, whilst the percentage of particles-plus-aggregates smaller than d as found by

aggregate analysis is B, the degree of aggregation is $\frac{A-B}{A}$, or expressed as a percentage, $100\frac{A-B}{A}$. In the present case, d has been chosen as 0·25 mm. as was done by Tiulin and also by Meyer and Rennenkampff (cited by E. W. Russell[11]).

For the present investigation it seemed desirable to provide a figure expressing the amount by which the state of aggregation has fallen short of the maximum possible for that particular soil. While it has been assumed as a practical guide that the state of aggregation of the uncultivated headland gives a rough indication of the maximum state of aggregation possible, it is realised that comparison with virgin land would be more satisfactory.*

The statement of the aggregation of the fields in terms of this potential aggregation for the soil was made by expressing the degree of aggregation for the fields as a percentage of that for the headland. The factor thus formed was called the "relative aggregation."

Using the data of Fig. 1, the degrees of aggregation and relative aggregations of the samples have been computed. (Table IV.)

TABLE IV. DEGREE OF AGGREGATION AND RELATIVE AGGREGATION.

Sample No.	Field	Degree of aggregation (%)	Relative aggregation (%)
S126	Uncultivated headland of field No.1.	53.5	100
S127	Field No.1	37.1	69
S128	Field No.2 (limed strip)	33.1	62
S129	Field No.2 (unlimed strip)	34.9	65

Stability of Aggregates to Wetting

The moisture characteristic of the aggregates sieved between 1 and 2 mm. was constructed for each sample with the moisture contents of the sample, expressed as percentage of oven-dry weight, plotted as ordinates, m, and corresponding pressure deficiencies in cm. of water plotted as abscissae, p. From each moisture characteristic a differential curve, with ordinates, $\frac{dm}{dp}$, and abscissae, p, was constructed. As a specimen of the kind of results obtained in this way, a typical graph, that for Sample S58, is shown in Fig. 2. Graphs similar to Fig. 2 were produced for all samples of sieved aggregates that were tested and the main findings from these graphs are stated in Table V.

* Two possible ways in which the headland soil might differ appreciably from a virgin patch of soil are that the roots of an adjacent gorse hedge may have altered the soil, and wind-blown particles including superphosphate and lime may have been trapped by the grass growing on it.

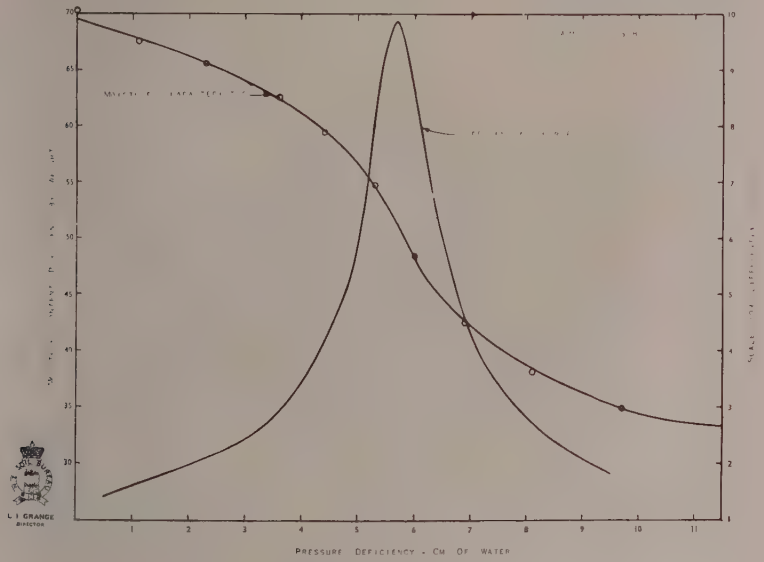

Fig. 2. Moisture Characteristics and Differential Curve for Aggregates 1.2 mm Diameter.

The stability factor listed in Table V is defined as the maximum or peak value of $\frac{dm}{dp}$ divided by the value of p at which the maximum occurs, i.e. stability factor $= \frac{dm}{dp}/p$ at peak of differential curve.

Table V includes for each sample the volume of pores drained between 0 and 10 cm. pressure deficiency. Since the sieved aggregates were all of fairly uniform size, the inter-aggregate pores were also of fairly uniform size and drained at a pressure deficiency of about 6 cm. water. Consequently, there was little water drained after a pressure deficiency of 10 cm. was reached, so that the volume of pores drained between 0 and 10 cm. pressure deficiency is, for these sieved aggregate samples, a close approximation to the "volume of large pores".

Total Porosity and Pore-space Distribution

In Table VI are listed total porosity and "volume of large pores" measurements, together with the soil particle densities, included in this table for convenience.

The simplest way of showing the distribution of pore-space for a soil is by expressing the "volume of large pores" as a percentage of the total porosity. This is shown in the sixth column of Table VI.

Discussion

Water-stable Aggregates

It is immediately seen on examining Table III and Fig. 1 that the soil of the uncultivated headland is much better aggregated than that of the cultivated fields. The difference between the limed and

TABLE V. MOISTURE CHARACTERISTICS OF 1-2 mm AGGREGATES

Sample No.	Field	Total porosity (%)	Volume of pores drained between 0 and 10 cm water (%)	Peak value of $\frac{dm}{dp}$	Value of p at peak (cm water)	Stability factor $\frac{dm}{dp}/p$
S59 }	Headland of No.1	69.6 }	34.4 }	20.7 }	4.85 }	4.27 }
S60 }	uncultivated	70.3 } 69.9	39.3 } 39.3	17.7 } 20.5	4.60 } 4.37	3.85 } 4.83
S61 }		69.9 }	44.2 }	23.2 }	3.65 }	6.38 }
S56 }	No.1. Recently	64.0 }	34.2 }	12.8 }	4.80 }	2.67 }
S57 }	ploughed	- } 64.1	- } 33.3	- } 11.3	- } 5.25	- } 2.20
S58 }		64.1 }	32.3 }	9.85 }	5.70 }	1.73 }
S62 }	No.2. Carrying	62.6 }	29.2 }	7.62 }	5.75 }	1.32 }
S63 }	one year old	63.5 } 62.7	34.0 } 31.2	- } 7.95	- } 5.93	- } 1.34
S64 }	pasture: limed strip	62.0 }	30.4 }	8.28 }	6.10 }	1.35 }
S65 }	No.2. Carrying	61.9 }	31.0 }	7.20 }	6.35 }	1.13 }
S66 }	one year old	62.9 } 62.6	31.2 } 31.5	8.22 } 7.56	5.00 } 5.62	1.64 } 1.36
S67 }	pasture: unlimed strip	63.0 }	32.2 }	7.26 }	5.50 }	1.32 }

TABLE VI. PORE-SPACE RELATIONSHIPS

Sample No.	Field	Soil density (g/cc)	Total porosity (%)	Volume of large pores (%)		Ratio of volume of large pores to total porosity (%)
S59 }	Headland of No.1	2.51 }	55.2 }	17 }		30 }
S60 }		2.52 } 2.51	55.9 } 54.1	19 } 18		34 } 32
S61 }	Uncultivated	2.51 }	51.3 }	- }		- }
S56 }	No.1. Recently	2.54 }	50.4 }	16 }		32 }
S57 }	ploughed	2.59 } 2.57	54.1 } 53.4	16 } 16		30 } 30
S58 }		2.57 }	55.8 }	16 }		28 }
S62 }	No.2. Carrying	2.58 }	46.7 }	- }		- }
S63 }	one year old	2.58 } 2.58	45.6 } 45.9	6 } 7		13 } 15
S64 }	pasture: limed strip	2.58 }	45.3 }	8 }		18 }
S65 }	No.2. Carrying	2.59 }	48.6 }	8 }		17 }
S66 }	one year old	2.59 } 2.58	47.0 } 46.7	7 } 8		15 } 16
S67 }	pasture: unlimed strip	2.57 }	44.5 }	8 }		17 }

unlimed strips of Field 2 is not at all significant, and although the aggregation for Field 1 is slightly better than that for Field 2, the difference is barely sufficient to warrant any conclusions being drawn. The figures for degrees of aggregation and "relative" aggregation (Table VI) demonstrate the differences between the fields and the headland in a very convenient way.

Compared with the few yellow-grey earth soils for which figures are available, the headland soil shows an appreciably higher degree of aggregation than related uncultivated soils. Some unpublished data for cropped fields, collected during a preliminary investigation into structure deterioration on other Canterbury wheat farms, are also available. They show that although individual fields had degrees of aggregation only slightly better than Fields 1 and 2, the corresponding uncultivated headlands were much less strongly aggregated than the headland of Field 1. Thus, despite the similarity of the states of aggregation of fields tested in the preliminary investigation to the present case, the "relative aggregation" (as defined previously) was

much lower in the latter instance. "Relative aggregation" measures the deterioration in structure from the uncultivated state and the fact that it is much lower for Fields 1 and 2 than for any other soil so far examined gives further reason for believing the deterioration in the present case to be severe. Although cropped fields on related soil types with similar low degrees of aggregation have been found, they do not appear to have deteriorated from the uncultivated condition as seriously, when judged by the figures for "relative aggregation".

Moisture Characteristics of the Sieved Aggregates

From Table V, it is seen that judged by each of the factors listed, viz. total porosity, volume of large pores, peak value of $\frac{dm}{dp}$, value of p at peak, and stability factor, the uncultivated headland has proved to be considerably better than the cultivated fields, and Field 1 to be slightly better than Field 2. There appears to be no difference between the limed and unlimed strips of the field. The analyses show a fairly wide variation within samples taken from the same site, but when considered all together, the conclusions given above are definitely established. An interesting observation is that the results for the peak value of $\frac{dm}{dp}$ give more significant differences between headland and fields than the stability factor. This appears to be contrary to the conclusions of Feng and Browning[6], who describe the stability factor as giving the best measure of the state of the soil structure.

The conclusions from the moisture characteristics are in agreement with those derived from the water-stable-aggregate analyses. However, the technique is more complicated than that for obtaining aggregate analyses and not so readily adaptable to routine measurements. Although it gives some insight into the nature of the soil-structure stability, it has proved in this investigation to be no better as a means of distinguishing between good and bad structure stability than the wet sieving technique. Water-stable-aggregate analyses should thus be made as a first step in examining the structure of yellow-grey earth soils, and the moisture-characteristic method reserved for more intensive studies where wet sieving does not throw sufficient light on the problem.

Total Porosity and Pore-space Distribution for Undisturbed Samples

A study of Table VI reveals two important facts. First, the uncultivated headland has a somewhat higher total porosity and a markedly higher volume of large pores than any of the samples from Field 2. Secondly, the pore-space distribution of the ploughed Field 1 closely resembles that of the headland and not, as might have been expected, that of the cultivated Field 2. The reason for the latter fact, which is at variance with the results of the measurements of aggregate distribution and stability already discussed, is that at the time of sampling, Field 1 had just been ploughed. A temporary improvement in aeration was thereby conferred on the soil, but since the structure stability was inherently poor for this field, such improvement in aeration did not produce stable soil aggregates, and was thus soon obliterated by the action of weather and subsequent soil cultivations.

A fuller interpretation of the pore-space distribution can be given by relating it to similar work reported by others. Much attention in the past has been given to the question of the optimum distribution of pore-space in soils for plant growth. Baver, who is frequently quoted in this respect, claims that "the ideal soil should have the pore-space about equally divided between large and small pores."[12] However, in actual cases the best distribution of pore-space will probably depend to some extent on soil type. Indeed, some evidence for such a dependence of optimum pore-space distribution on soil type can be seen from the work in Russia of Doyarenko and Kvasnikov (quoted by Russell[11]). Doyarenko found that for podzolic soils around Moscow, 50–55 per cent of the total pore-space should be occupied by large pores for best results, whereas Kvasnikov, in contrast, showed the optimum figure for semi-arid chernozems to be much lower, viz. 35–40 per cent. It is likely that for any soil where the rainfall is low, the optimum pore-space distribution will tend to Kvasnikov's figure rather than to Baver's.

The value of 32 per cent for the proportion of pore-space occupied by large pores which was found to apply to the uncultivated headland soil may be regarded as close to the optimum for this soil type if it is conceded that under the dry climate of South Canterbury, the optimum pore-space distribution would tend to a value similar to that found in Russia for semi-arid chernozems. Contrasting with the uncultivated headland soil which may thus be regarded as approaching a condition of good soil structure, is the pore-space distribution of Field 2, where only 16 per cent. of the total pore-space consisted of large pores. This is conclusive evidence that Field 2 has deteriorated considerably in soil structure, an important reason, no doubt, for the poor crop yields obtained from this field. But low yields were also associated with Field 1, which shows very little difference from the headland in the proportion of pore-space occupied by large pores, although from both wet-sieving analyses and aggregate-stability determinations it is seen to be in very nearly as poor a physical condition as Field 2. As mentioned above, this apparent anomaly can be explained by the fact that the pore-space distribution of Field 1 was measured immediately after the field had been ploughed.

Conclusion

The chemical examination shows both cultivated and uncultivated soils to be low in potassium. This may have been a contributory cause of the low yields obtained from the fields, but insufficient is known of the potash regime of these soils to confirm this suggestion.

Probably more important, is the deterioration of the soil structure with cropping, as revealed by the measurements of degree of aggregation and stability factor. The decline in organic-matter content found by the chemical analysis is probably associated with this physical deterioration.

The degree of aggregation as determined by the simple wet-sieving technique appears to give, for rapid survey purposes, sufficient indication of the changes which occurred in the soil structure. Moisture characteristic determinations which are more time consuming, seem to offer little obvious advantage for this purpose.

The pore-space relationships found for the recently ploughed soil suggest that values for the volume of large pores can be misleading as an indication of the state of soil structure if measured too soon after cultivation operations have taken place.

The limitations of the investigation do not allow of a categorical assertion that the structure deteriorated more than it would have done had sound farm management been followed, but this is probably the case. It has often been shown that declining crop yields ensue when soil structure deteriorates, and Baver[13] recently cited an outstanding case where non-capillary pore-space (i.e. the volume of large pores as used here) was 3·5 per cent for cropped land compared with 25 per cent for virgin land; the corresponding sugar beet yields were 1·5 tons an acre, and more than 12 tons an acre. While in the present investigation neither the decline in crop yields nor the changes in physical properties of the soils are as great as reported by Baver, it is clear that significant physical changes have occurred which can be shown by several laboratory methods.

Acknowledgments

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AERIAL TOP-DRESSING TRIALS: EQUIPMENT AND FLYING TECHNIQUES USED AND MEASUREMENT OF DISTRIBUTION OF PHOSPHATE

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Summary

IN order to investigate the possibility of using aircraft to mechanize more fully top-dressing of hill country, trials were undertaken with a Grumman Avenger aircraft.

A gravity-feed hopper of 1-ton capacity was designed and fitted to the aircraft. Trials carried out at Ohakea under experimental conditions indicated that a dropping height of 400 ft. was most suitable, with 2 ch. between centres of runs.

A control system was developed in which the aircraft was guided in for its dropping run by a ground controller, who relayed his instructions to the pilot by radio. Suitable flying techniques were developed.

Full-scale trials were carried out in the Wairarapa, where 1,100 acres of steep hill country were top-dressed satisfactorily, with 137 tons of fertilizer in 57 hours flying time.

These trials proved that aerial top-dressing is practicable and reasonably accurate even on the steepest hill country.

INTRODUCTION

MUCH of the excess run-off and erosion occurring in New Zealand hill country to-day is due to the inadequate vegetative cover provided by poor pasture.

Levy[1] and Sears[2] of the Grasslands Division, Department of Scientific and Industrial Research, have shown how superphosphate, when applied to suitable grass and clover pastures under controlled grazing, will start a fertility cycle leading to greatly increased pasture growth. Their technique has been followed by progressive hill-country farmers.

Suckling[3], also of Grasslands Division, working at Te Awa in collaboration with the Manawatu Catchment Board and using finance voted by the Soil Conservation and Rivers Control Council, has demonstrated the general applicability of flat land pasture techniques to Te Awa hill country.

Unpublished progress reports of extension trials made in South Hawkes Bay, Taihape district and elsewhere have proved the general applicability of the Te Awa results to most phosphate-deficient hill country with adequate rainfall. However, the rugged terrain and inaccessibility of many such areas has made ordinary methods of top-dressing an expensive and very arduous task. A possible alternative is to carry out the top-dressing by means of aircraft.

Following representations from farmers in the Wairarapa, in particular Mr L. T. Daniell, the Soil Conservation and Rivers Control Council arranged for the setting up in Wellington of a co-ordinating committee, representative of interested organisations and State De-

partments to investigate methods of aerial top-dressing and to undertake aerial top-dressing trials.

PRELIMINARY TRIALS AT OHAKEA

Equipment Used

Air Department undertook the task of adapting aircraft equipment and flying techniques to suit the work. For the preliminary trials, a Grumman Avenger aircraft of good load-carrying capacity, powered with a 1600 h.p. R.2 400 Wright Cyclone engine, was selected. An overload fuel tank, which normally fitted into the bomb bay of the aircraft, was adapted to carry a load of one ton of superphosphate. The bottom of the tank was removed and, leading down to the opening gate, were fitted sloping sides, which projected a few inches through the bomb doors, the centre parts of which were removed.

The hopper had to be removed for re-loading and for this purpose a trolley was built up from hydraulic torpedo lifts, which could raise and lower the hopper as required. A small compartment at the front of the hopper with a small opening was reserved for seed. The opening gate on the hopper was controlled from the bomb aimer's position in the aircraft.

Ground trials with the hopper were satisfactory, but air trials were essential to test the performances of the hopper when air borne, and to determine what happened to the contents of the hopper after release.

Trial runs were made at Ohakea in September, 1948. It was planned to fly the aircraft at minimum safety speed into the wind in a straight and level course over the aerodrome, the target area to be marked out by smoke bombs and white strips.

Commercial grade 44/46 superphosphate was tried in the first run. The coarse particles spread over a wide area, while the fine dust which comprised a big percentage of the total load remained airborne and drifted off the aerodrome. The release was made at an altitude of 500 ft, and while the time taken for the hopper to empty was not accurately recorded, it exceeded the estimated 17 sec. This slow discharge was due to arching occurring in the hopper, the manure packing down solidly because of the vibration. Superphosphate pellets were then used. The pellets consisted of commercial superphosphate which would pass a $\frac{3}{8}$-in. sieve, but be retained on a $\frac{1}{4}$-in. sieve; they were a by-product of manufacture of commercial superphosphate corresponding to "hillside" superphosphate. The average weight of each pellet was 0·25 g.

In order to ensure a steady flow, an agitator consisting of a rod running the full length of the hopper with branches projecting at right angles down into the openings was then fitted 6 in. above the openings. The rod was given a longitudinal movement of 3/16 in. at 300 cycles per minute.

Results of Preliminary Trials at Ohakea

Four runs were made into the wind at minimum speed approximating 115 m.p.h. in straight and level flight at altitudes of 600, 400,

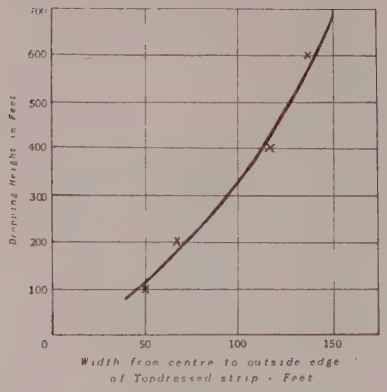

FIG. 1—Relation between dropping height and width of strip.

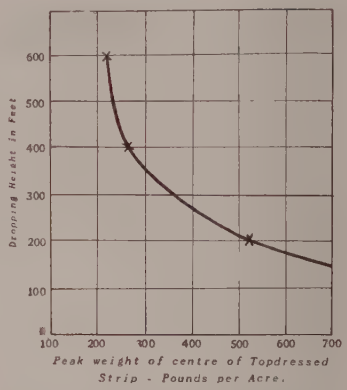

FIG. 2—Relation between dropping height and quantity of fertilizer per acre.

200 and 100 ft. above aerodrome level. The average time to release was 17 sec. per ton, which was estimated to cover a strip 40–45 ch. long. The average width of each strip was as shown in Fig. 1, in which half the width of spread of each strip is plotted against the approximate height at which each strip was laid down. While the basic data used to obtain this relationship between height above ground and width of spread was meagre, the following interpretation is suggested:

The pellets enter the air with a high forward speed; if the shape of the pellet is irregular there will be exerted on it an aerodynamic force which is comparatively high in relation to the mass of the pellet. The high forward velocity is quickly lost, and the pellets continue on their downward journey with varying lateral components of velocity. The extent to which the turbulence of the propeller slip-stream contributes to this lateral component is not known, but it is thought to be small.

Generally speaking, for a single-engined aircraft dispersal is proportionate to height up to approximately 600 ft.; above this height any further increase in width is insignificant.

This preliminary trial of width of spread was largely verified by a small-scale trial in 1949, and by the large-scale field trials in the Wairarapa. Field trials in the Wairarapa were conducted at heights above ground-level of from 200–600 ft. The greatest measured width of strip was 85 yd. for 550 ft. altitude, and the smallest width 45 yd. for an altitude estimated at 200 ft. It should be noted that owing to the difference in time of fall between large and small particles, a cross wind will increase the spread by carrying the latter further down-wind.

Concurrently with measurements of total width of spread at Ohakea, measurements were made of the weight of superphosphate per acre deposited at uniform distances from one side to the other of the strip at right angles to the direction of flight. Figs. 2 and 3 record the results. Fig. 2 records peak weights per acre in the centre of each strip for each flight at altitudes of 200, 400 and 600 ft. It is

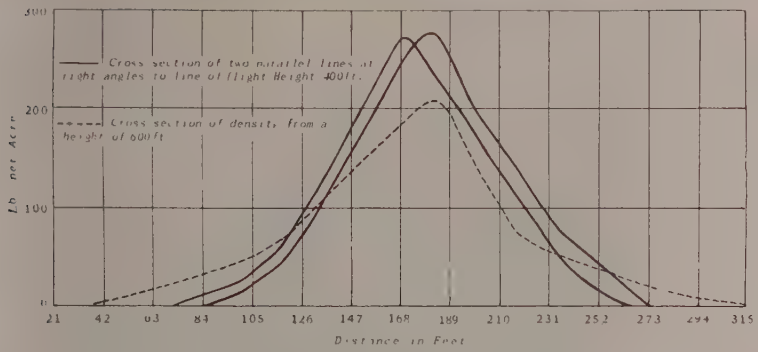
Cross section of two parallel lines at right angles to line of flight Height 400ft.
Cross section of density from a height of 600 ft
Lb. per Acre
200
100
0
21 42 63 84 105 126 147 168 189 210 231 252 273 294 315
Distance in Feet

FIG. 3. Cross-section of distribution pattern for two top-dressed strips.

apparent that peak weights per acre are in inverse proportion to height.

It can be assumed that in still air the distribution pattern changes very slowly for heights in excess of 600 ft. Between the altitudes of 600 and 400 ft. there is an increase of only 60 lb. per acre in peak density, while from 400 to 200 ft. there is a large increase in peak density from 275 lb. at altitude 400 ft. to 550 lb. at altitude 200 ft. The need for an average top-dressing of about 2 cwt. superphosphate per acre pegged the likely satisfactory working altitude at between 400 and 600 ft.

Fig. 3, in which width in feet from one side to the other of the strips laid down at altitudes of 400 and 600 ft. are plotted against pounds per acre, gives the cross-section of distribution of superphosphate across the strip. A similar shaped curve occurred for altitudes of both 400 and 600 ft. Increasing altitude beyond 400–500 ft. did not give an improved pattern of distribution, but tended to give excessive side drift when any cross-wind was present, making the

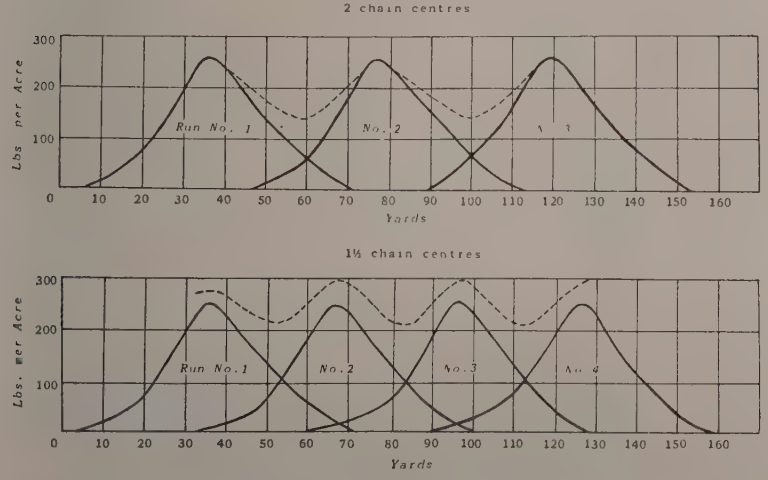

FIG. 4. Calculated distribution pattern for spreading runs at 2-ch. and 1½-ch. centres. Altitude, 400 ft.

placing of the superphosphate within the target area more uncertain; this fixed the most suitable altitude at about 400 ft., a height at which flying is reasonably safe.

The curves of cross-sectional distribution across the strip at 400 ft. show a density varying from a trace at the sides to 275 lb. in the centre. From this it was obvious that an overlap would be necessary to iron out extreme peaks and troughs across a field. Two theoretical spacings were considered in graph form using the Ohakea 400-ft. trial data. In Fig. 4 are shown the calculated distribution patterns for strips flown at 2-ch. and 1½-ch. centres; at 2-ch. centres the overlap is 32 yd., the peak density, 275 lb. per acre, and the trough density, 110 lb. per acre—quite a large variation; at 1½-ch. centres the overlap is 44 yd., the density 290 lb. per acre, and the trough density 225 lb.—a much smaller variation.

While under ideal precision-flying conditions and control techniques the 1½-ch. spacing between centres of strips gives much better distribution than the 2-ch. spacing, it was considered too exacting for field conditions; the 2-ch. spacing was, therefore, adopted for field scale trials.

Flying Technique Developed

From the foregoing data it can be seen that from the flying point of view, the requirement was to bring the aircraft over the area to be top-dressed in a series of parallel runs 2 ch. apart.

As the pilot cannot see the ground just in front of and below the Avenger, a system of radio control was devised, involving two-way contact between the pilot and control point on the site.

The system of control was as follows:

(a) The ground controller on arrival at the site assessed the direction in which the runs should be made—taking into consideration the preference to fly into the wind—and positioned himself on the leeward end of the area.

(b) The controller then positioned himself one chain in from the starting boundary, aligned a prismatic compass along the intended line of flight and observed the bearing.

(c) Sighting beyond the commencement point of the run, he assessed clearly defined pin-points which were on the projection of the intended line of flight.

(d) On arrival of the aircraft in the area, radio contact was established, and the controller passed to the pilot the vector to be flown, i.e. the reciprocal of the bearing observed on the compass.

(e) The controller would then direct by radio the pilot's approach to and flight over the target. These radio directions were given throughout the run over the area, and on completion of the run the aircraft returned to base.

(f) On completion of the run, the controller would move his apparatus 2 ch., at right angles to the line of flight and repeat the methods outlined above.

The definition of the release point at first gave a certain amount of trouble, but it was found that if a ground-marker strip was laid at the down-wind end of the area to be top-dressed—this one marker satisfied all runs—the hopper operator was able to see the marker quite clearly, thus ensuring a standard starting point on all runs. Each strip then approximated 40–45 ch. long with 2 ch. between the centre of each strip. It was calculated that each run, while cover-

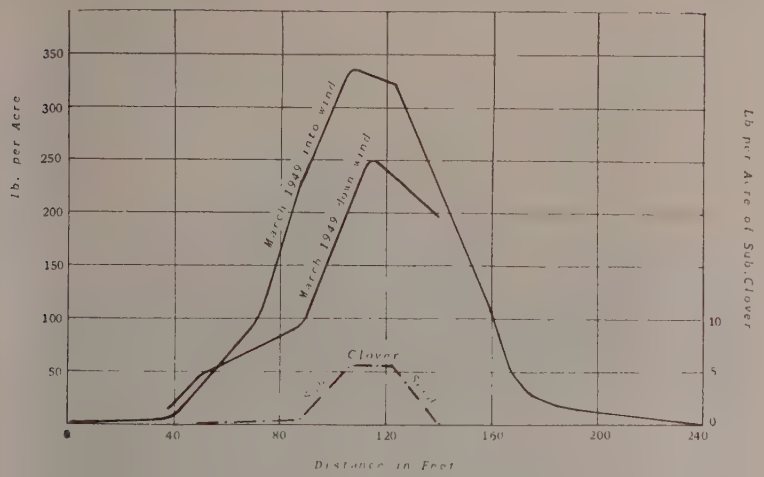

FIG. 5. Cross sections of distribution pattern with mixed superphosphate chips and subterranean clover for flights into and down wind.

ing 45 ch. by 3½ ch., would effectively top-dress 45 ch. by 2 ch. or a total of 9 ac. to the ton.

FURTHER OHAKEA TRIALS

The results of further trial runs are shown on Fig. 5. These distribution patterns agreed with those obtained in September 1948 for an aircraft flying on straight and level flight at an altitude of 400 ft. above ground-level. In these trials, subterranean and white clover seed totalling about 50 lb. was tipped into the hopper with the fertilizer and released with it. Only in the case of the subterranean clover was it practicable to separate the seeds from the superphosphate dust. Fig. 5 also shows the spread of the subterranean clover over the strip top-dressed. A slight cross-wind 5–6 m.p.h. was sufficient to almost

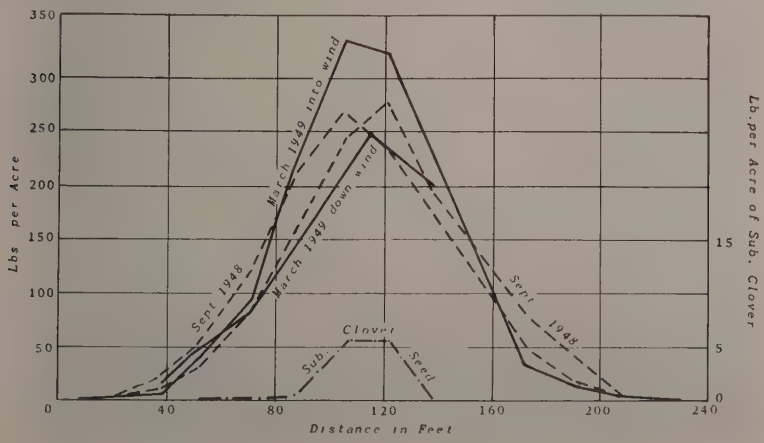

FIG. 6. Distribution pattern for all experimental flights at 400 ft.

completely separate subterranean clover from white clover, the white clover falling to the lee side of the strip, the subterranean clover falling over the central 50 ft. at peak weight of 5 lb. per acre.

Fig. 6 illustrates the similarity of distribution of all runs of 400-ft. altitude measured at Ohakea.

Trials in Wairarapa

Equipment Employed in Measuring Distribution

In the Ohakea trials all samples had been collected by sweeping up fertilizer and seed from the 10 square-yard hexagonal blocks comprising the runways.

As field scale trials to spread 120 tons of superphosphate pellets over 1,000 acres on 12 farms in the Wairarapa hill country were being planned, it became necessary to design a collapsible, light portable collector which would enable the collection of samples on steep hill country with the minimum of time and labour and the maximum efficiency.

These collectors served a two-fold purpose. Firstly, they provided reasonably accurate information concerning what was happening to the superphosphate once it left the hopper, thus enabling the officer in charge of operations to make modifications or improvements in flying techniques. Secondly, by supporting information as to the distribution of the fertilizer on the ground, they made it possible to compare the effectiveness of aerial top-dressing with hand top-dressing.

The development of a suitable light portable collector which would retain all pellets, clover seed, and dust proved difficult. The opening of this collector had to be on a horizontal plane, and the collector

Fig. 7. Collector set up for reception of fertilizer pellets.

FIG. 9. Layout of collectors, Morrison's, Awatoitoi.

had to retain all material dropping at both high and low terminal velocities.

Fig. 7 shows the finally designed collector, which was found to retain all particles dropping into it. The mouth of the collector could be kept on a horizontal plane even on slopes of up to 35°, thus ensuring that each collector-mouth presented the same area for the reception of pellets. It was realized that these collectors measured the distribution pattern just before the superphosphate pellets hit the ground. No rapid method of measurement could be discovered to examine the distribution after the bouncing pellets came to rest. It was thought prior to the trials that there would be a pronounced tendency for the superphosphate to come to rest on sheep and cattle tracks, and on all other flatter areas. From visual observation during the field trials, it would appear that the average pasture cushioned the impact and reduced bounce to a minimum, so that the pellets remained within a short distance of the original point of impact. Even steep slopes of 40° received a fair distribution of pellets, since fall is nearly vertical when superphosphate pellets are dropped from 400 ft.

Loading Method

On 3 May 1949, operations commenced at Masterton. Fig. 8 shows a Y-shaped ramp, on to which the aircraft could taxi for loading operations, the empty hopper being wheeled on to one arm of the Y, while the full one was wheeled in from the other arm. The first measurements with the collectors was made on Wairarapa trials at Mr Morrison's farm, Awatoitoi. (Fig. 9.)

Measuring Technique

Four sites were selected along the side of the field at the outside edge of the first 2-ch. strip to be top-dressed. These sites were approximately 5 ch. apart, covering a distance of 15 ch. in the centre of the 40-ch. long strip to be top-dressed. Starting from the above four selected points, twelve collectors were put out in each line at right angles to the line of flight, each collector being spaced 8 yd. apart. The plane then flew over on its first run, dropping the superphosphate, samples of which were retained in some of the collectors. Individual collectors caught superphosphate pellets from several runs, but as soon as it became apparent that no further pellets were being caught, the small collecting bags at the apex of the cone of the collector were removed and numbered, and four or five collectors moved to the other end of the row; this procedure was repeated for each of the ten flights distributing one ton per load.

Because of insufficient manpower, some of the collectors in Line C and D were not moved before the next load of phosphate was distributed; in the case of Line D, this resulted in inadequate data, which could not be used. Although a break also occurred in samples for Line C, the remaining weights were plotted up.

Results and Discussion

Fig. 10 records the measurement of distribution at the trial on Mr Morrison's farm.

The next detailed collection of samples was made at Mr Grove's farm, Bushgrove. A less ambitious layout of collectors was chosen;

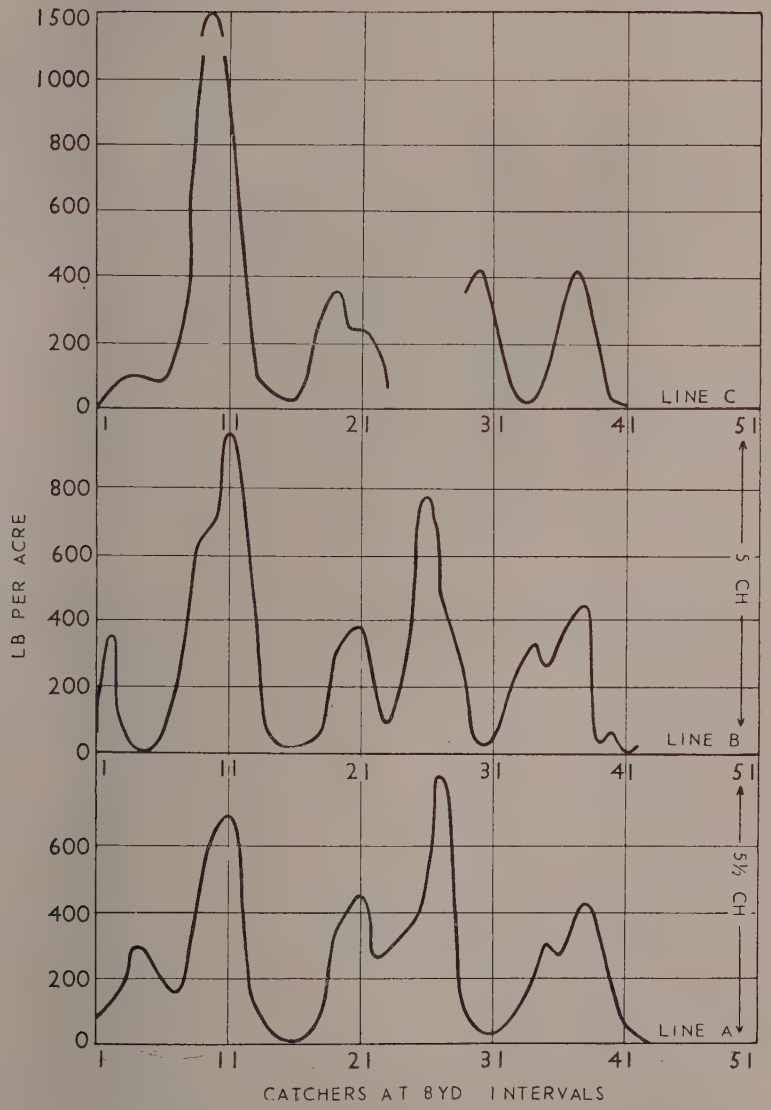

FIG. 10. Distribution pattern of field-scale trials at Morrison's, Awatoitoi.

the nine men doing the job were carefully briefed following experience gained at Morrison's and close liaison was maintained with the air-ground control point. The terrain was steep and rugged, the approach to the target area good, but a very rapid turn-off at the end of the run was necessary to avoid high hills. Two significant alterations were intentionally made in the flying techniques. Firstly, the system of release of the hopper initiated by the pilot—who necessarily had poor forward and downward visibility and was intent on watching

TABLE I. RESULTS OF THREE AERIAL-TOPDRESSING TRIALS IN WAIRARAPA

DETAILS	FARM		
	MORRISON'S	GROVE'S	KEBBELL'S
AREA TOPDRESSED (ac.)	67	87	100
QUANTITY OF FERTILIZER SOWN			
Total (tons)	10	10	10
Per Acre (cwt)	2.98	2.3	2.0
FLYING TIME (hr)	4.00	4.10	5.05
EXTENT OF AREA TOPDRESSED			
Length of Strip (ch)			
Maximum	-	52	59
Minimum	-	40	38
Average	-	48	52.7
Width of Strip (yd)			
Average Line A	-	81	49
B	-	75	71
C	-		82
FLYING ERRORS			
Starting Point Error (ch)			
Maximum	23	8	9
Minimum	0	1	2
Average	-	4	5.5
Finishing Point Error (ch)			
Maximum	-	3	4
Minimum	-	0	0
Average	-	1.5	1
Deviation off Course (yd deviation per chain run)			
Maximum	-	5	1.6
Minimum	-	0	0
Average	-	1.7	.79
DISTANCE OF CENTRE OF EACH TOPDRESSED STRIP FROM ITS ASSOCIATED CONTROL POINT (yd)			
Maximum	-	91	44
Minimum	-	7	0
Average	-	28.7	20.1
DISTRIBUTION OF FERTILIZER ON EACH STRIP			
Percentage of area with under 100lb per acre.			
Line A	38	13	36
B	44	30	20
C	52		23
Percentage of area with 100-300lb per acre.			
Line A	36	60	55
B	24	52	49
C	26		44
Percentage of area with over 300lb per acre.			
Line A	26	27	11
B	32	18	31
C	22		33
DISTRIBUTION OF FERTILIZER OVER WHOLE FIELD			
Percentage of total area under 100lb per acre	45	21.5	26
Percentage of total area 100-300lb per acre	28	56.0	49
Percentage of total area over 300lb per acre	27	22.5	25

his altitude and speed while at the same time following ground control radio directions—was abolished in favour of release initiated by the navigator. Secondly, the speed of 115 m.p.h. was increased to approximately 125 m.p.h. This gave a larger margin of air safety, slightly reduced the peak density and slightly increased the length of strip. The air ground-control point was situated about 15 ch. from the starting point in order to obtain good visibility along the whole of the aircraft's approach.

The objects of measurement were:

(1) To obtain cross-sectional distribution over the whole width of the field in two places.

(2) To note the width of spread of each run and the location of the runs one to another.

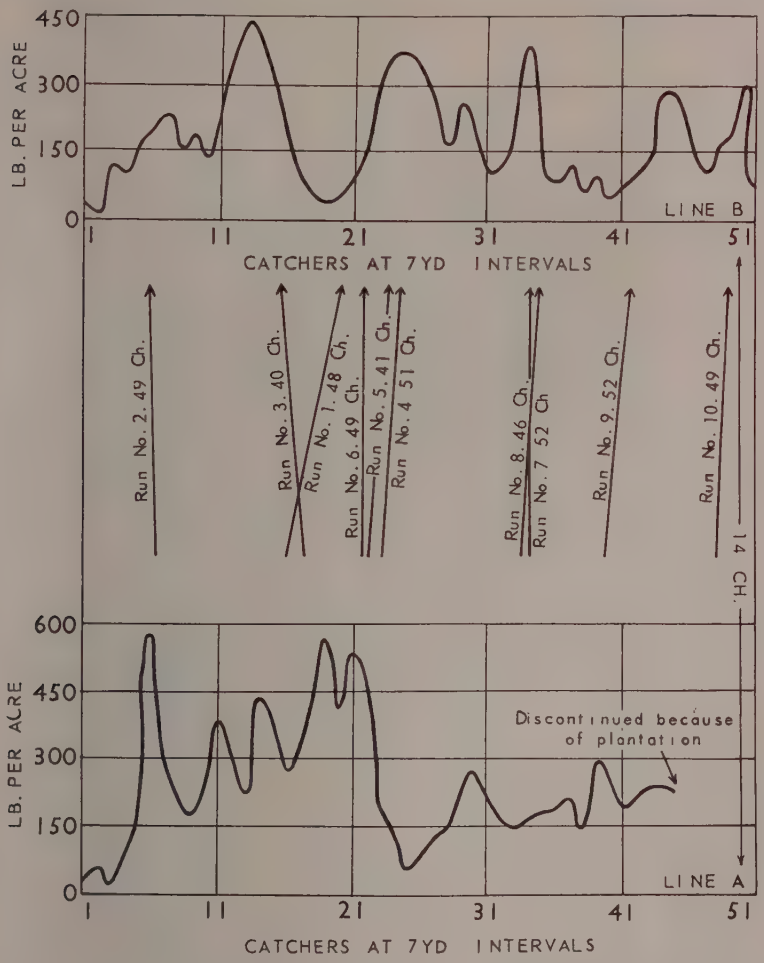

FIG. 11. Distribution pattern of field-scale trials at Grove's.

(3) To obtain the total length of each run, as well as the starting and finishing points.

(4) To map the location and direction of each run.

The method was similar to that evolved at Morrison's except that only two lines of collectors were used. The results are shown graphically in Fig. 11.

It must be realized that on steep country placing collectors with the collecting mouth on the horizontal plane tends to give an exaggerated picture of weight spread per acre. As was pointed out, however, the object of these measurements was two-fold; to examine ground coverage, and to assist the development of a technique by recording the distribution pattern. It is fair to assume that minor irregularities on the ground cannot be individually treated or considered in aerial

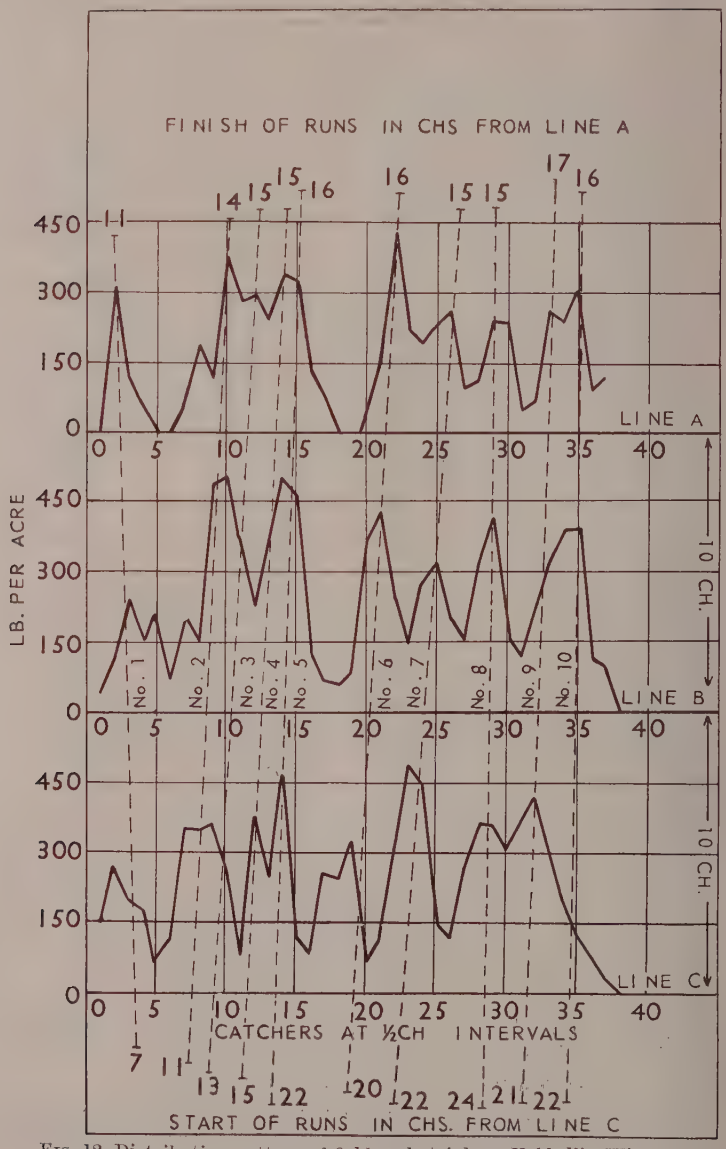

FIG. 12. Distribution pattern of field-scale trials at Kebbell's, Winiata.

top-dressing. If the pattern of aerial distribution is as near perfect as possible 1 yd. from the ground, it is unlikely that anything further done in the air will affect this ultimate ground distribution. Consequently the collectors were placed horizontally at 7-yd. intervals, at right angles to the lines of flight.

The next field scale measurement was made at R. W. Kebbell's, Winiata, and is recorded in Fig. 12.

A slightly more elaborate lay-out of three lines was decided on in view of the advantages of a three-point check compared with a two-point check.

The method was exactly the same and aimed at obtaining the same information.

In Table I the information obtained from the three trials is tabulated to facilitate comparison.

It is apparent from this table that both in ensuring optimum distribution of fertilizer and accuracy in dropping within the target area, a progressive improvement had been obtained.

While the completion of Morrison's trial demonstrated that aerial top-dressing of hill country was practicable, it was apparent that considerable improvement in the distribution of fertilizer within the target area was imperative to ensure effective utilisation of the fertilizer. The area covered was too small. The variation of rate of fertilizer per acre from point to point of the field fell within extremely high limits. The accuracy of release was subject to extreme fluctuation, and, of course, ground-controlled precision flying had not yet been attained by the very competent pilots and ground control crew.

Experience at Morrison's was responsible for a considerable improvement in distribution at Grove's. Although the terrain was much more difficult, necessitating better judgment on the part of the pilots, a larger area was covered with a more satisfactory average rate per acre with the limits between high and low rates per acre greatly reduced. The starting and finishing error was also greatly reduced. Deviation off course, accompanied by dropping of fertilizer partly or wholly off the target selected by the ground control point, was, however, still excessive. Factors contributing to this error were the unpredictable wind direction caused by the funnel-shaped target and the need to establish the ground control point at the starting point for dropping rather than at the finishing point.

Team work developed and experience obtained as a result of the above two trials produced a substantial improvement in all phases of accuracy of spread and optimum distribution in Kebbell's trial. Ten tons of fertilizer were spread over 100 acres at an average of 2 cwt. per acre. A longer dropping run made possible by still air and a faster air speed aided this. The starting and finishing accuracy developed at Grove's was maintained. Deviation off course was reduced to a minimum of $\frac{3}{4}$-yd. deviation per chain of spreading run; consequently, no intersection of lines of flight occurred. A considerable improvement in laying the fertilizer down within the target area of each run also occurred, many flights being dead on course. In addition, a very satisfactory distribution of fertilizer at rates which would ensure optimum utilization were obtained over the whole 100 acres.

It is apparent from these trials that the result obtained at Kebbell's is as good as can be obtained with the hopper equipment now in use. The actual measured cross-sectional distribution has many points of similarity with the calculated distribution depicted in Fig. 4.

CONCLUSIONS

The field trials with a Grumman Avenger aircraft have shown that a heavy aircraft is satisfactory for use in top-dressing steep hill

country. Further investigations are required to find the effect on cost of using larger aircraft with 5-ton and 10-ton loads. From an operational and administrative point of view these aircraft present difficulties.

With the present type of gravity-feed hopper, at least 40-ch. length of field will be needed for each ton of phosphate. However, as control of runs becomes more difficult when they are over a mile in length, precision top-dressing of one paddock will not be possible with the technique used with the Grumman Avenger aircraft. Either new methods or new equipment will need to be developed. One possible method would be to top-dress an area of responsive country owned by several farmers, with each farmer paying a proportion of the cost on a per-acre basis. Another possible alternative suitable for a large paddock or a whole farm would be to design a hopper which could be opened and closed to drop a suitable fraction of the total load on each of several consecutive runs over the target during the one flight.

New equipment for large aircraft should perhaps concentrate on greatly increasing the width of spread, as a doubling of this width would halve the length of top-dressing run. It would also partly eliminate the need for extremely accurate flying to give a complete and even ground-cover of fertilizer.

Investigations are being carried out with a view to designing a hopper which, by giving the fertilizer pellets initial lateral impetus, will ensure a greater width of spread. The influence of size and shape of pellets on their width of spread and accuracy of drop, and the reasons for the large variations in peak weight of fertilizer at the centre of the top-dressed strip are also being investigated.

As a result of the trials already carried out, pasture practices previously of mainly academic interest because of impracticability can now be generally utilized by the hill-country farmer.

On phosphate-responsive soils with adequate rainfall, hill-country pastures may be readily improved by the introduction of suitable clovers and the application of superphosphate fertilizer. Aerial top-dressing for the first time puts in the hands of all hill-country farmers an implement for large scale hill-country top-dressing.

Acknowledgments

The thanks of the authors are due to those who assisted in some measure in the provision of facilities and/or the collection of records; to officers of Royal New Zealand Air Force engaged on both the Ohakea and Wairarapa trials; to officers of the Soil Conservation and Rivers Control Council at Palmerston North and Wellington; to members of the draughting room staff, Ministry of Works, Palmerston North; to officers of the Department of Agriculture, Masterton, and the Wairarapa Catchment Board; and to the photographers for permission to reprint photographs.

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SOIL DISINFECTION

XII. EFFECT OF FUMIGANTS ON GROWTH OF SOIL FUNGI IN CULTURE

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(*Received for publication, 21 June 1951*)

Summary

The commercial soil fumigants: chloropicrin, Shell D-D, Dowfume N, ethylene dibromide, ethylene dichloride and Dowfume 40, were tested *in vitro* on the following soil fungi: *Verticillium dahliae, V. albo-atrum, Colletotrichum atramentarium, Fusarium oxysporum* var. *auriantiacum, F. lini, Corticium solani, Sclerotinia sclerotiorum, Phytophthora cryptogea, P. cactorum*, and *Pythium ultimum*.

The most effective fumigant, chloropicrin, killed all test fungi at dosages of 3–4 p.p.m. Efficacy of the other fumigants varied, but in general dosages much greater than those for chloropicrin were required to kill the test fungi.

Introduction

It has been shown previously (Jacks, 1944) that both chloropicrin and Shell D-D controlled *Pythium* damping-off in soil. Shell D-D was, however, less effective than chloropicrin (Jacks, 1946, 1948) in controlling *Verticillium* wilt. These results were confirmed in further experiments (unpublished) where chloropicrin and Shell D-D were also found effective against *Phytophthora cryptogea* Pettybr. and Laff.

Zentmyer and Kendrick (1949), using *in vitro* tests on agar and in soil with *Fusarium solani f. phaseoli, Phytophthora cinnamoni, Corticium solani* and *Thielaviopsis basicola*, found that chloropicrin killed these fungi at 1·9 ml per cu. ft. At 2·1 ml, however, 1·3 dichloropropene did not kill *Fusarium*, and at the same concentration Dowfume N did not affect *Corticium*. Ethylene dibromide, at 2·1 ml per cu. ft, was effective against *Phytophthora* while 4·2–8·4 ml were required to kill the other fungi. At 8·4 ml per cu. ft, 1,2 dichloropropane was ineffective.

The tests here described were carried out in an attempt to assess the relative value of several fumigants against some of the more common soil fungi under controlled environmental conditions. It is hoped that this method will permit rapid fungicidal evaluation of new fumigants.

Experimental Methods

Prune or potato dextrose agar media was poured into quart jars until the base was uniformly covered. A 4-mm disc from a fungous colony on potato dextrose agar was placed in the centre of the media. Inoculations were carried out on different days to allow for different growth rates of fungi, and in this manner colonies of similar size ($\frac{1}{8}$–$\frac{1}{4}$ of the jar diameter) were obtained. Jars were kept at room temperature, viz. 16 ± 4°C. Colony diameters were measured at regular intervals until hyphae reached the media margin. A colony

not resuming growth 14 days after exposure to fumigants was considered killed.

The following fungi were used, and the source of isolations is given in brackets: *Verticillium dahliae* Kleb. (wilted tomato stems); *V. albo-atrum* Reinke and Berth. (wilted potato stems); *Colletotrichum atramentarium* (Berk and Br.) Taubenh. (potato stems); *Fusarium oxysporum* Schl. var. *aurantiacum* (Lk.) Wollenw. (wilted cucumber stems); *F. lini* Bolley (wilted linen flax stems); *Corticium solani* (Prill and Delacr.) Bond (infected potato tubers); *Sclerotinia sclerotiorum* (Lib.) de Bary (wilted potato stems); *Phytophthora cryptogea* (tomato stems); *P. cactorum* (Lib. and Cohn) Schroet. (gooseberry bark), and *Pythium ultimum* Trow (tomato seedlings).

The fumigants used were: chloropicrin (Larvacide) (98 per cent pure); Shell D-D (50:50, 1,2 dichloropropane: 1,3 dichloropropene); Dowfume N (50 per cent 1,3 dichloropropene plus chlorinated propanes); ethylene dibromide (over 90 per cent pure); ethylene dichloride (over 90 per cent pure); and Dowfume 40 (42 per cent ethylene dibromide).

The fumigants were measured as parts per million of jar volume into glass dishes resting on the sealing discs (Fig. 1). Sealing discs consisting of a thin metal disc lined with rubber give an airtight seal when fastened to jars with the aid of metal screw bands. Graduated pipettes (0·1, 1·0 and 10·0 ml respectively) (Fig. 2) were used to measure 10,000, 1,000, 800, 600, 300, 100 p.p.m., etc. Sealing discs and dishes were removed 48 hours after treatment, and the lids were then loosely replaced on jars.

Fig. 1. Method of fumigating preserving jars (quart size). Fungous culture in base of jar, fumigant in glass dishes placed on sealing discs which are fastened to jars by metal screw bands.

Photo.: S. A. Rumsey.

FIG. 2. 1-ml pipette and rubber bulb used for measuring small amounts of fumigants.

Photo.: S. A. Rumsey.

TABLE I.

Effect of soil fumigants on growth of *Verticillium dahliae*, *Fusarium lini*, *Phytophthora cryptogea* and *Pythium ultimum* in culture

Treatment	Concentration (p.p.m.)	Increased colony diameter in m m 14 days after treatment			
		Verticillium dahliae	Fusarium lini	Phytophthora cryptogea	Pythium ultimum
Larvacide	30	0	0	0	0
"	100	0	0	0	0
"	300	0	0	0	0
Shell D-D	30	32	0	0	0
" "	100	0	0	0	0
" "	300	0	0	0	0
Dowfume N.	30	30	40	0	0
" "	100	0	0	0	0
" "	300	0	0	0	0
Ethyl. dibromide	30	30	46	80*	70*
" "	100	27	16	0	0
" "	300	0	0	0	0
Ethyl. dichloride	30	30	50	90*	90*
" "	100	34	40	80*	80*
" "	300	0	0	0	0
Dowfume 40	30	39	51	90*	90*
" "	100	39	42	90*	80*
" "	300	31	48	0	0
Check	—	46	71	100*	100*

* Surface of media covered before 14 days, estimated growth given.

RESULTS AND DISCUSSION

Experiment 1

A range of dosages was tested which it was hoped would allow differentiation between various fumigants through their killing effect on four fungi. Records of linear growth were completed 14 days after fumigation. All fumigants under test killed the fungi at the concentration of 10,000 p.p.m. Dowfume 40 failed to kill *Verticillium dahliae* at 1,000 p.p.m. and *V. albo-atrum* at 300 p.p.m. Ethylene dichloride and Dowfume 40 were not effective against *Phytophthora cryptogea* and *Fusarium lini* at 100 p.p.m. Chloropicrin, Dowfume N and Shell D-D killed all four fungi at dosages as low as 100 p.p.m.

Experiment 2

In this experiment lower dosages were tested on a larger number of fungi. Results are given in Table 1.

Verticillium dahliae was killed by chloropicrin at all concentrations under test; *Fusarium lini* by chloropicrin and Shell D-D; *Phytophthora cryptogea* and *Pythium ultimum* by chloropicrin, Shell D-D and Dowfume N. Of the remaining fumigants ethylene dibromide was more effective than either ethylene dichloride or Dowfume N.

Experiment 3

Further tests were carried out at substantially reduced concentrations to determine the lowest dosage at which each fumigant would kill the test fungi.

Results of tests with all materials and fungi, as summarized in Table II, give approximate minimum dosages of fumigants required to kill the test fungi.

TABLE II.

Minimum concentrations of fumigants killing soil fungi in culture.

Soil fungi	Concentration in p.p.m.					
	Larvacide	Shell D-D	Dowfume N.	Ethyl. dibromide	Ethyl dichloride	Dowfume 40
Verticillium dahliae	4	60	60	200	300	>1000
Verticillium albo-atrum	3*	100	30*	300	> 300	> 600
Colletotrichum atramentarium	3*	30	100	> 300	100*	> 600
Fusarium oxysporum	3*	10*	> 100	300	> 300	> 600
Fusarium lini	3*	3*	60	200	300	> 800
Corticium solani	3*	30	100	100*	300	600
Sclerotinia sclerotiorum	3*	100	100	100*	300	600
Phytophthora cryptogea	3*	10*	30	100	300	300
Phytophthora cactorum	3*	10*	10*	30*	100*	100*
Pythium ultimum	3*	3*	6	100	200	300

* Lowest dosage tested.

Chloropicrin at the lowest dosage tested, killed all test fungi except *Verticillium dahliae*. Shell D-D was more effective against *Fusarium*, *Phytophthora* and *Pythium* than against *Verticillium*, *Sclerotinia*, *Corticium* or *Colletotrichum*. The four other fumigants were less effective than either chloropicrin or Shell D-D.

Susceptibility to fumigant action was variable within species of the same genus; thus, *Verticillium dahliae* was more resistant than *V. albo-atrum*; *Fusarium oxysporum* was more resistant than *F. lini*; and *Phytophthora cryptogea* was more resistant than *P. cactorum*.

CONCLUSION

Results suggest than it is possible to place these fungi into three groups of relative resistance to the action of fumigants: (1) *Verticillium dahliae*; (2) *V. albo-atrum*, *Colletotrichum*, *Fusarium*, *Corticium* and *Sclerotinia*; and (3) *Phytophthora* and *Pythium*.

As minimum lethal dosages given by Zentmyer and Kendrick (1949) are considerably higher than those found in these experiments, it is assumed that higher dosages of fumigants than those required *in vitro* are required to kill fungi in soil.

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CONTROL OF WEEDS IN TOBACCO SEEDLING BEDS

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Summary

In order to find an effective alternative method to steam sterilisation for controlling weeds in tobacco seedling beds, the following substances have been examined: Calcium cyanamide, calcium cyanamide-urea, chloropicrin, D.D., formalin solution, formalin dust and methoxone dust. Trials carried out over four years have shown that none of the substances tested is as effective as steam. Calcium cyanamide did, however, give promising results.

Introduction

To the tobacco grower who wishes to raise his own plants directly from seed, weeds in the seedling bed present the greatest problem. This is also true to a lesser degree of the grower who buys boxes of seedlings, and subsequently pricks out. Tobacco seed is usually sown towards the end of August. As at this time of the year the soil is still cold, the seed may take three weeks to germinate, and for the first week or two growth of seedlings is slow. Weed seeds which have lain dormant during the winter germinate ahead of the tobacco, and because they are usually of a vigorous species, grow rapidly and soon smother out the tiny tobacco seedlings. In direct seeded beds, weeding is impractical. While it can be done in pricked-out beds, the process is costly, and is a potent means of spreading mosaic. The problem can be overcome by steam sterilisation of the soil, but unfortunately only a limited amount of equipment is available for such treatment. New equipment is costly, and because it is used for a short period of the year only, it represents a high capital outlay in proportion to the work accomplished. Any alternative means of controlling weeds, therefore, which would be reasonable in cost, simple to use, and did not require expensive equipment would be of great benefit to the industry. Chemical alternatives, however, bring their own problems. Anything that will check the growth of weeds will check tobacco, and it is usually necessary to take certain precautions to make sure that any toxic after effects have been dissipated. With the object of finding a possible alternative to steam a number of chemicals were tried out.

Review of Literature

The problem of weeds in the seedling beds is common to all tobacco growing countries. Anderson and Swanbeck[1] in Connecticut, found steaming superior to all other methods for controlling weeds, and while they recommend chloropicrin as an alternative, comment that it is not so effective for weed control. Hill and Klingman[2] in North Carolina recommend calcium cyanamide or a calcium cyanamide-urea mixture, with the reservation that under certain conditions there may be a residual toxic effect, and that neither chemical was so effective on the heavier soils. Carr[3] in Georgia had similar results, as also did McGee *et al*[4] in South Carolina. Haney[5], working in Australia, found that calcium cyanamide controlled weeds, but under some conditions reduced the stand of tobacco. "D.D." appeared to

stimulate weed growth. In Canada, McEvoy[6] found that while steam sterilisation was the most effective method, chloropicrin also controlled weeds. Formaldehyde did not entirely eliminate weeds, but killed both germinating seed and growing weeds.

EXPERIMENTAL PROCEDURE

For the purpose of the experiment, the seedling beds were filled with new soil each year. The soil was a sandy loam generally taken from an old fence line where it had been growing grass and weeds for several seasons. Consequently, it was in good physical condition, was well supplied with organic matter, and contained a representative population of weed seeds.

The beds used were 24 ft. long and 4 ft. wide, the usual width adopted by growers. Beds were divided into sections 6 ft. long. As far as possible, the treatments were randomised over several beds. Apart from the various chemical treatments under trial, the beds received the usual cultural treatment; viz. addition of 3–8–8 fertilizer in the spring at ¾ lb. per square yard, and direct seeding at the same time as the rest of the crop, i.e., late August or early September. Treatments were carried out as follows:—

Steam was applied by the grid method, at a pressure of 90–100 lb., for a period of 10 min. Temperatures after steaming ranged from 200 to 210°F at a depth of 6 in.

Calcium cyanamide—a fertiliser containing 20 per cent nitrogen, was applied at the rate of 1 lb. per square yard of bed area. Two-thirds of the quantity was sprinkled evenly over the surface and forked in to a depth of 4 in. The remaining third was then broadcast on the surface and lightly raked in. The bed was left open to the weather. Treatment was carried out on an average 30 days before sowing the seed.

Calcium cyanamide-urea (Urea, 48 per cent nitrogen) was used as a mixture at the rate of ½ lb. calcium cyanamide and 1 lb. urea per square yard of bed, applied as described above for calcium cyanamide.

Chloropicrin (Tear gas), a liquid which under suitable temperature conditions evaporates to a penetrating gas, was injected to a depth of 4 in. at 12 in. square intervals, after the soil had been forked over thoroughly and raked level. The surface was sealed by thoroughly watering and then covered with wet sacks which were kept in place for 72 hr.

"D.D.", a liquid, which evaporates readily when exposed to the atmosphere, was applied like chloropicrin by injecting 2 ml. at 12 in. square intervals, watering thoroughly, and covering with wet sacks.

Formalin Solution was applied slowly with a watering can, allowing the liquid time to soak in. The ground was then covered with wet sacks which were removed after 72 hr. During the first year, a 2 per cent solution at 2 gal. per square yard was used, but it was found that the quantity of liquid was excessive. For the second year, half the quantity at double the strength was used, i.e., 1 gal. per square yard of a 4 per cent solution.

Formalin Dust was made by mixing 1 pt. of commercial formalin with 7 lb. of koalin as a carrier. It was sprinkled over the bed at the rate of 2 oz. per square foot, and worked into the top 2–3 in., with a rake.

Methoxone Dust, commercial weed killer was applied to the soil at the rate of 400 lb. per acre, and raked into the surface soil. The beds were direct seeded in the early spring in the usual manner.

RESULTS

Weeds were pulled and counted six weeks after sowing, and a further count was made three weeks later. The results of the various treatments are set out in Table I.

TABLE I. EFFECT OF VARIOUS CHEMICAL TREATMENTS ON THE GROWTH OF WEEDS

Treatment	Number of Weeds per square foot of ground					
	1945	1946	1947	1948	1950	Average 1946–50
Unsteamed	20.0	68.7	18.4	37.5	101.7	56.6
Steam Sterilised	0.5	6.3	0.6	1.4	5.0	3.3
Formalin	8.9	43.1	-	-	-	-
Formalin Dust	-	28.5	-	-	-	-
Chloropicrin, 4 ml (Autumn)	-	22.8	2.6	10.0	30.7	16.5
Chloropicrin, 2 ml "	9.1	37.8	-	-	-	-
Chloropicrin, 4 ml (spring)	-	-	4.0	-	-	-
"D.D."	14.9	-	-	-	-	-
Calcium cyanamide	-	11.6	1.9	14.0	33.3	15.2
Calcium cyanamide-urea	-	5.9	1.8	13.8	-	-
Methoxone	-	59.2	-	-	-	-

On the unsteamed plots there was a vigorous growth of weeds each season, although the density varied from year to year depending on the soil used. On a section not weeded, the tobacco was almost entirely smothered. In all cases steaming controlled weeds to a degree where subsequent weeding of the beds was either completely eliminated or was negligible.

Calcium cyanamide resulted in a considerable reduction in the number of weeds, the results one year approaching those of steam. The same supply of chemical was used over the four years of the trial, and the results suggest that it may have lost some of its effectiveness through storage. Where some beds were covered during the winter months and were not exposed to the winter rainfall, a residual toxic effect was noticeable, evident by a serious reduction in the stand of seedlings.

The *calcium cyanamide-urea mixture* was slightly better than the calcium cyanamide alone in controlling weeds. With both these highly nitrogenous fertilizers the plants produced were dark green, soft and sappy. It was found that this could be corrected by omitting the nitrogen from the seedbed fertilizer.

With *chloropicrin* the 2 ml. autumn application was not satisfactory. The 4 ml. spring application was discontinued as other work with chloropicrin indicated autumn application being more effective on account of the higher soil temperature prevailing at that season of the year.

The 4 ml. autumn application brought about a considerable reduction in the weed population. While this result was not as good as could be desired, the remaining weeds could probably have been removed by a hand weeding.

"D.D." brought about little reduction in the density of the weed population.

Formalin, either in solution or as a dust, brought about some reduction in the number of weeds, but neither method could be regarded as an effective control.

Methoxone applied as a dust to the soil did not have any effect on the growth of weeds.

DISCUSSION

Of all the treatments under trial, steam was definitely the best. It gave almost complete control of weeds without adverse effects of any kind. Calcium cyanamide resulted in a marked reduction of the weeds. If consistent fresh supplies of this chemical could be obtained, it offers distinct possibilities for weed control. It has, however, certain limitations on account of its toxic after effect. For this reason calcium cyanamide must be applied 90 days before seeding. Even so, in a dry winter, there may not be sufficient moisture to leach the chemical out of the ground, and adverse after effects may result. Chloropicrin gave only fair control of weeds, but is very useful in tobacco seedling beds because of its fungicidal properties. It is emphasised that for effective penetration and distribution of the gas, a minimum soil temperature of 45°F. and preferably higher is necessary.

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CONTROL OF LATERAL GROWTH IN FLUE-CURED TOBACCO BY CHEMICALS

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Summary

With a view to finding an effective means of controlling lateral growths on flue-cured tobacco plants, the following substances were tested: Mineral oil, maleic hydrazide, methyl ester of naphthalene acetic acid, and butoxy ethanol ester of 2.4.5-T. The results indicated that the substances checked the growth of laterals in varying degrees. Maleic hydrazide and mineral oil were sufficiently effective to offer promise for use on a commercial basis.

Introduction

It is the normal practice to top flue-cured tobacco by removing the flower head with about a foot of stem and several of the upper leaves. The operation is usually carried out when the flower head is fully extended but before many of the flowers have actually opened. The object is to allow the remaining top leaves of the plant to attain a greater development, and also to prevent the spent blossoms falling on to the leaves and setting up centres of infection which cause blemishes. As soon as the flower head is removed, lateral growths develop rapidly in the axils of the remaining leaves. These laterals must be removed, generally necessitating three laterellings of the crop, involving the use of considerable labour at a time of the year when demands for labour are heavy. If some means could be found of controlling these lateral growths without otherwise injuring the plant it would be of immense practical assistance to the industry.

Review of Literature

In recent years considerable work has been carried out with plant hormones or growth regulating substances, and tobacco, among other crops, has received its share of attention. Steinberg[1, 2] reported the successful control of lateral growths under greenhouse conditions. Calvert[3], also working in the greenhouse, found that certain chemicals inhibited sucker formation. McEvoy[4, 5], working in the field with a variety of chemicals, secured promising results. He also found differences in varietal response to different chemicals. Anderson[6, 7], also working in the field, first reported success with naphthalene acetic acid and later with other substances. All these workers found that for each chemical there was only a narrow range of permissible concentration; outside this range harmful results were observed.

Experimental Procedure

The experiments described below were carried out in the field on a crop of flue-cured tobacco, variety Harrison's Special. The crop was a well grown one which would yield 1500 lb. of cured leaf per acre. Until topping, which was done by hand on 31 January, it had been cultivated in the usual manner. At this stage about half the flowers were fully open, a little further advanced than usual for this operation. The plants were topped down to 16 leaves, and all treatments were applied within an hour of topping. Plots consisted of single rows of 30 plants each, replicated three times.

Mineral Oil (Liquid Parrafin, Chemists' quality) was applied to the top two or three inches of the stem with a paint brush, and allowed to trickle down the stem. The quantity used averaged 6 ml. per plant.

Maleic hydrazide was used at two strengths, viz., 0·5 per cent and 1.0 per cent. The original 30 per cent stock solution was diluted with water and a small quantity of casein spreader added. It was applied as a spray to the top of the stem and the upper four leaves of the plant at the rate of 10 ml. per plant.

Methyl ester of Naphthalene Acetic Acid, which was received in liquid form, was thoroughly mixed with French chalk as a carrying agent to produce a dust containing one per cent by weight of the ester. The dust was applied to the plants by being shaken through a muslin bag over the top of the stem and the adjacent leaves at the rate of 6 oz. per 100 plants.

Butoxy ethanol ester of 2.4.5-T was made up and used in an identical manner and at the same strength as the ester of naphthalene acetic acid.

Controls: Adjacent rows were topped at the same time but received no treatment.

RESULTS

The day following treatment, the upper leaves of the plants treated with methyl ester of naphthalene acetic acid were, compared with plants submitted to other treatments, definitely curved downwards. On the second day the leaves treated with butoxy ethanol ester of 2.4.5-T were similarly curved downwards. At the end of five days, plants in both plots appeared to be recovering somewhat, but a tendency to curving remained with both until the end of the season. At no time did any of the other treatments show any harmful effects.

On 2 March, 30 days after treatment, the laterals were removed from ten plants in each replication and weighed. Results are given in Table I.

TABLE I—WEIGHT OF LATERALS FROM 10 PLANTS 30 DAYS AFTER TOPPING.
(Average of three replications)

Treatment	*Weight of laterals* lb.	oz.
Control	11	2
Mineral Oil	1	15
Maleic hydrazide 1%		9
Maleic hydrazide 0.5%	2	9
Naphthalene acetic acid	5	11
Butoxy ethanol ester of 2.4.5-T	3	14

All treatments have controlled lateral growth to a greater or lesser degree. Notes on individual treatments are:—

Control: Laterals were strong and vigorous, up to 2 ft. long.

Mineral Oil: Laterals were all small, the largest being up to 4 in. long; many were killed completely. There was no apparent damage to the leaf even at the base where it frills round the stem.

Maleic hydrazide: 1·0 per cent strength. Laterals were very stunted, none more than 2 in. long and all very narrow as in frenching. There was no noticeable damage to the leaves of the plant.

0·5 per cent strength: Appearance was similar to those treated with 1·0 per cent spray, but lateral growths were a little longer.

Methyl ester of naphthalene acetic acid: The upper lateral growths were reduced to about 4 in. long, but the laterals arising lower down the stem were much stronger than the corresponding ones of the controls. There was a slight but definite downward curving of the upper leaves.

Butoxy ethanol ester of 2.4.5-T: Results were rather erratic. In some plants complete control was obtained, while others had one strong terminal lateral with some smaller lower laterals; others again were intermediate. In a number of plants, there was a distinct bending of the top of the stem to one side and a slight but definite downward curving of the upper leaves.

Discussion

Of the treatments under trial that with maleic hydrazide was the most effective and shows distinct promise. Particularly with the one per cent application, the laterals were reduced to negligible proportions, and their growth after the conclusion of the experiment was still so retarded as to be of little consequence. The labour involved in applying a spray would be small compared to that of two or three laterellings.

Mineral oil also gave good practical control of laterals, and if topping and treatment had been carried out a little earlier in the season, would have been even more effective. Application would present some difficulties, but these could be overcome.

Butoxy ethanol ester of 2.4.5-T resulted in some measure of control, but the results were erratic. This may have been due to slight variation between the plants, as it is known that with some hormones the time of application is very critical.

Methyl ester of naphthalene acetic acid resulted in some measure of control, but insufficient to be of any practical value. Both these latter two substances produced an undesirable distortion of the upper leaves.

Acknowledgments

The naphthalene acetic acid and the butoxy ethanol ester of 2.4.5-T were supplied by Messrs. Ivon Watkins Ltd., of New Plymouth. The maleic hydrazide was received from the Naugatuck Chemical Export. New York. Thanks are due to both these firms.

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CHANGES IN THE SALT CONTENT OF SOME SALINE SOILS AT LAKE ELLESMERE IN CANTERBURY

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Summary

(1) Soil salinity is shown to increase with distance from the lake margin for a few hundred yards, and then to decline progressively with reduced flooding.

(2) The 0–4-in. samples are consistently more saline than the 4–8-in. samples, but at still greater depths salt content may increase with proximity to the highly saline water table that may exist well back from the lake edge.

(3) Soil salinity is low in winter and early spring, but rises to high values in summer, though these may be temporarily depressed by rain.

(4) The inter-relations between salt content and alkalization seem to be affected by the organic matter content and the seasonal changes in salinity.

INTRODUCTION

THE salt content of saline soils is important in determining (in association with other edaphic factors) the vegetation that they bear, and also in its effect on other soil conditions and on pedological processes. The relationship between the salinity of the soils of the flats bordering Lake Ellesmere and their plant communities will be discussed elsewhere. It is intended to record here some of the seasonal and spatial changes in the salinity of these soils, found during an investigation of the ecology of the plant communities of the area, and to note their effects on some of the soil properties.

EXPERIMENTAL METHODS

The plant communities are arranged in a series of zones of varying width, more or less parallel with the lake edge. Within each of these zones a plot 40 ft. by 8 ft. was located; subsequent point analyses of the vegetation of these plots showed that they were typical of the various zones. Each plot was sampled every two or three months with a tube sampler at the 0–4-in. and 4–8-in. levels by taking 10 cores at random in the plot; this number had previously been found to provide an adequate sample for the analyses made.

The cores were bulked, air-dried and sieved before analyses, which were carried out in duplicate. Soil salt content was measured conductimetrically on 1 : 5, soil : water suspensions at 20°C after mechanical shaking for an hour. The specific conductivity values thus obtained have (in Table I) been converted to a percentage of salt in the soil by using a conversion factor of 344 which was obtained from gravimetric analyses. Chlorides were determined by a Mohr titration on an aliquot of the same soil suspension, and were found to follow the salinity values very closely, the chlorides of sodium and magnesium being the main salts in the soil solution. Sulphates were present in only slight amounts, while Na_2CO_3 and $CaCO_3$ were of negligible quantity. The pH of the 1 : 5 soil suspension was measured potentiometrically. The exchangeable cations were determined, after preleaching of the soluble salts with 70 per cent ethyl alcohol, by leaching with

TABLE I. SALT CONTENT AND OTHER PROPERTIES OF SOME ELLESMERE SOILS

Plot	Plant community	Distance from lake (yd)	Depth of Sample (in)	Salt content * (%) May	Aug.	Nov.	Feb.	Chlorides* (%) Feb.	Moisture content * (%) Feb.	Concentration of soil solution (%) Feb.	Organic matter (%) May	Base saturation (%) May	pH May
B.2.	Mimulus-Lilaeopsis	-	0-4	1.00	0.55	1.31	1.15	0.77	47.7	2.4	5.7	88	6.2
			4-8	0.70	0.52	-	-	-	-	-	-		-
B.3.	Spergularia marginata	100	0-4	1.71	1.11	2.75	1.83	1.10	41.4	4.4	8.9		6.5
			4-8	1.00	0.93	1.06	1.22	0.86	30.2	4.0	-		6.5
B.4.	Salicornia-Triglochin	400	0-4	2.71	1.04	3.89	3.00	1.77	45.0	6.7	13.4	84	5.6
			4-8	1.37	1.01	1.18	1.69	1.00	25.0	6.8	-		6.0
B.6	Agrostis stolonifera	550	0-4	0.87	0.68	1.33	1.36	0.56	52.0	2.6	16.6	88	6.0
			4-8	0.59	0.31	0.37	0.58	0.25	24.2	2.4	-		6.4
C.1.	Pioneer Salicornia	-	0-4	0.80	0.71	1.95	1.17	0.86	16.5	7.1	1.7	100	6.5
			4-8	0.74	0.76	0.93	0.99	0.72	18.8	5.3	-		6.8
C.2.	Salicornia-Triglochin	300	0-4	2.58	1.98	4.60	5.57	3.30	41.4	13.4	14.9	83	5.0
			4-8	1.19	1.52	1.18	1.95	1.15	25.0	7.8	-	96	5.9
C.3.	Salicornia-Hordeum	800	0-4	1.24	0.70	1.56	2.36	1.89	35.1	6.8	7.3	99	5.8
			4-8	0.54	0.76	0.79	1.19	0.83	11.2	10.6	-	100	6.8
C.5.	Salicornia-Hordeum	1100	0-4	0.18	0.09	0.38	0.90	0.43	6.2	14.4	3.5		6.7
			4-8	0.10	0.09	0.14	0.23	0.12	2.8	8.2	-		7.1
C.6.	Juncus maritimus	1100	0-4	0.23	0.09	0.61	1.35	0.88	16.5	8.2	4.7		7.1
			4-8	0.18	0.10	0.27	0.30	0.19	6.7	4.5	-		6.7
C.7	Juncus maritimus	1200	0-4	0.20	0.06	0.39	0.81	0.39	16.5	4.9	3.1	98	6.8
			4-8	0.17	0.09	0.13	0.24	0.11	7.7	3.1	-	100	6.7
C.8	Ryegrass pasture	1800	0-4	0.07	0.03	0.05	0.09	0.04	4.1	2.2	-		6.4
			4-8	0.05	0.03	0.05	0.08	0.04	2.8	2.8			7.5

* Calculated as percentage of air-dry soil

neutral *N.* ammonium acetate, and precipitation. Calcium was precipitated as oxalate, magnesium as hydroxyquinolate, and potassium as cobaltinitrite. Sodium was determined by difference from the total exchangeable bases.

RESULTS

In Table I is given a selection of the results of analyses carried out on two series of plots: the B series was located on the silt loam soil of the Selwyn River spit; the C series was located below Greenpark on the sandy loam soils of the wide flats on the north-east side of the lake. Both series are arranged in order of increasing distance from the lake edge.

DISCUSSION

Horizontal Gradient in Salinity

In tidal areas, Doak (1931) and Chapman (1938) have found that there is little difference between the salinity of each of the lowermost zones, and only at the higher levels is there a regular fall in salt content. The rate of this decline is dependent mainly on the climatic conditions and the rate of increase in level.

At Lake Ellesmere, which is non-tidal, with a subhumid climate, and where the rise in the level of the flats is gradual, there is initially a rise in the salt content of the soil; this reaches a peak about a quarter of a mile from the usual lake edge, and then declines progressively with increasing distance from (and height above) the lake. In areas affected by fresh water springs, as in the area below Doyleston, saline conditions may exist only for a distance of one hundred yards from the lake edge; on the other hand, in sandy soils with little rise in level, as in the area below Greenpark, the saline zone may be over one mile wide.

The gradients in the concentration of the soil solution are similar, but less marked. At the lake edge the concentration approaches that of the lake water; at slightly higher levels it rises with the increased soil salinity; at still higher levels there may be rather less salt, but the soil is drier (except under the tall-growing *Juncus* communities) and the concentration of the soil solution still high. Thereafter, with reduced flooding, both salt content of the soil and concentration of the soil solution decline.

Profile Gradients

Doak (1931) found that in the lower, more saline zones the 0–9-in. samples were more saline than the 9–18-in. samples, whereas the reverse was the case in the upper, less saline zones. In general, the 0–3-in. samples were less saline than the 3–9-in. samples. However, only winter (August) samples were recorded. Chapman (1938) examined the seasonal variations in profile salinity gradients in a tidal area; in general, there were no marked profile gradients, but there was a slight tendency, evident in all the zones, for the top-soil samples to be more saline than the subsoil samples in summer, and less so in winter.

At Lake Ellesmere it may be seen that the 0–4-in. samples have a consistently higher salt content than the 4–8-in. ones, the difference being very marked in summer, but hardly noticeable in winter. In terms of the concentration of the soil solution, the difference is much

less marked, and in winter or after heavy summer showers no gradient is apparent within the top 8 in. of the soil.

However, at varying depths below this surface soil—the soil of the root zone—there is present a saline water-table which seems to maintain a level more or less in equilibrium with the slow changes in the level of the lake, and which—in the sandier soils at least—may extend at least one mile from the lake edge. Thus on the wide flats below Greenpark in January 1950, when the lake level was low, the water-table was just below the surface of the soil at the lake margin, and contained about 1·4 per cent of salts, having approximately the same salinity as the lake water; half a mile from the lake edge, it was 3 ft. 1 in. down and contained 5 per cent of salt; three-quarters of a mile from the lake, it was 3 ft. 6 in. down and had a concentration of 8 per cent. The salinity of this water may be derived from the residual salt in the soil; this possibility, however, is excluded for those areas which have had the salt leached out by the functioning of artesian bores, but which have developed high salinities again once the supply of fresh water is removed. In some zones the salt content of the ground-water may be derived from the downward percolation of partially evaporated lake water which has flooded the area. In the uppermost zones, however, where flooding is rare or slight, and where there is little salt in the surface soil, the only source of the saline ground-water would seem to be the percolation of lake water back through the permeable sands of the substratum, apparently with progressive concentration by evaporation. If the lake level rises, this saline water-table may rise to within a few inches of the soil surface in the upper zones. In these upper zones, scattered more or less circular "salt pans," occupied solely by *Salicornia*, are present, and it seems probable that their formation is similar to that described by Raeside (1948) for the salt pans of Central Otago.

Fig. 1—A "salt pan," occupied solely by scattered plants of *Salicornia australis*, situated about three-quarters of a mile from the usual lake margin on the wide flats below Greenpark.

Seasonal Changes

Chapman (1938) found a marked annual drift in the salinity of the soils of the Norfolk and North American marshes, where the salt content is fairly low in winter and early spring, but reaches high values in summer. Even occasional showers in summer may considerably depress the salt content, as shown by Oliver as early as 1906, while Adriani (1948) has shown that the less pronounced annual drift in the Dutch marshes compared with those of the Mediterranean region is due to the frequent heavy showers in summer in the former area.

At Lake Ellesmere there is a marked annual drift, the salinity falling in late autumn and winter, and rising rapidly in early summer to high values.

The general rise in summer was obscured somewhat by low December values, but these were probably due to the fall of 2½ in. of rain two days prior to the collection of the December samples, as after three days of fine weather the salinity had again reached a high level.

In general, the annual drift in salt concentration is more pronounced in the more saline zones than in the less saline ones, and more marked in the top soil than in the subsoil. In winter both the 0–4-in. and 4–8-in. samples show a reduced salinity, indicating that the salt has been moved to deeper horizons. After summer showers, however, whereas the salt content of the topsoil samples may decline, that of the 4–8-in. samples may rise, indicating only slight movement of the salts with occasional rain.

The rapidity and extent of these changes indicate the great mobility of the salts in the soil solution, and suggest that it is undesirable to quote critical salinity values (whether average or maximum) for any species without reference to the type of salts, their profile distribution, and their seasonal variation.

Associated Soil Changes

In the presence of such large quantities of sodium chloride in the soil solution, a certain amount of alkalization of the exchange colloids is inevitable, and in most cases there is just sufficient exchangeable Na + K (15–20 per cent of the cation exchange capacity) for the soils to be included in the saline-alkali soil class of Magistad (1945), though they are by no means solonetzic. Despite the fairly high degree of base saturation, however, the soil pH values are not markedly alkaline, probably because magnesium has entered the exchange complex more extensively than the highly hydrated Na ion which is dominant in the soil solution. The soils of the most saline—the *Salicornia-Triglochin*—zone consistently show the lowest pH values and the lowest percentage base saturation. This condition may be partly due to the high organic matter status of this zone, as the more organic matter there is in the topsoil, the greater the difference in pH betwen topsoil and subsoil. But it may also be associated with the annual drift in soil salinity; where this falls to a low level in winter, as in the less saline zones, the exchangeable cations may be sufficiently active to be displaced by the percolating cations of the soil solution, with consequent alkalization; where fairly high salt levels exist even in winter, ionization of the exchangeable cations may be considerably repressed, and only active cations, such as those of hydrogen and magnesium, may effect any displacement.

For this reason, the annual drifts in pH and exchangeable cations were examined. Chapman (1938) has reported a marked annual drift in exchangeable calcium and none in exchangeable sodium, but as his method of analysis did not take into consideration the customary distinction between the exchange complex cations and those in the soil solution his results are not pertinent to the problem of the relationship between soil salinity and the process of alkalization. For the Ellesmere soils, no marked annual drifts in the pH values were evident, although there was a tendency for these to be lower in the winter. Similarly, the exchangeable bases did not exhibit any pronounced drifts, although there was a tendency for calcium and magnesium to be highest in the summer, whereas sodium was rather higher in the winter.

Acknowledgments

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TECHNIQUE FOR OBTAINING ASEPTIC SEEDLINGS

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Summary

A DESCRIPTION is given of a seed-sterilization apparatus which allows the separate processes of surface decontamination, washing with sterile water, and subsequent treatment with the desired sterilizing agent to be carried out in the absence of non-sterile air. The method of operation is described and relevant data given concerning duration of sterilization with specified seeds.

INTRODUCTION

IN the Soil Bureau laboratory the necessity to accomplish complete sterilization of seeds and their subsequent germination under sterile conditions arose as one of the pre-requisites for the successful application of Gerretsen's method[1] for aseptic cultivation of plants. The method is based on an earlier work published in 1935 by the same author,[2] wherein the apparatus for sterilization of seeds was not described in full, but was stated as being similar to that used by Petri.[3]

Since no detailed knowledge of the form of this apparatus could be found in either of Gerretsen's papers, and because the original paper of Petri was not available in this country, it was decided to construct apparatus based closely on the description given by Gerretsen.

DESCRIPTION OF APPARATUS

The sterilization chamber consists of a standard glass-joint dropping funnel head (Quickfit and Quartz Catalogue No. D4/23) with side arm for the application of vacuum. This fits on to a collecting flask, which in this case was a 350-ml. conical flask with a B24 socket. The open end of the dropping funnel is closed with a langite cork* through which pass three glass tubes and two wires as shown in Fig. 1. The ends of these wires, which project into the sterilization chamber, are bent at right angles to the vertical and turned inwards. With the ends so turned, they are able to support a perforated glass bucket (BC24 in the above catalogue) of the type used in a blood cholesterol extraction method. The seeds are placed in this bucket during sterilization.

Suspended above the sterilization chamber are three bottles equipped with metal bands and suspension loops. Such bottles normally contain protein hydrolysate solution and are used in hospitals for administration of simple amino acids by venoclysis or hypodermoclysis. Their design has been found admirable for this seed sterilization apparatus. In Fig. 2b, the bottle on the left contains alcohol for the preliminary surface sterilization; the middle bottle contains sterile water for washing away residual alcohol and fungicide after draining the seeds; the bottle on the right holds the fungicide.

* It has been found that langite corks are slightly pervious to air. In the author's experience this does not affect the sterility of the air in the sterilization chamber, providing that the end of the cork which fits into the chamber is wetted each time with alcohol and fungicide. However, a rubber stopper may be used instead, providing that it is fitted with a small bacterial filter tube with a stopcock at the lower end.

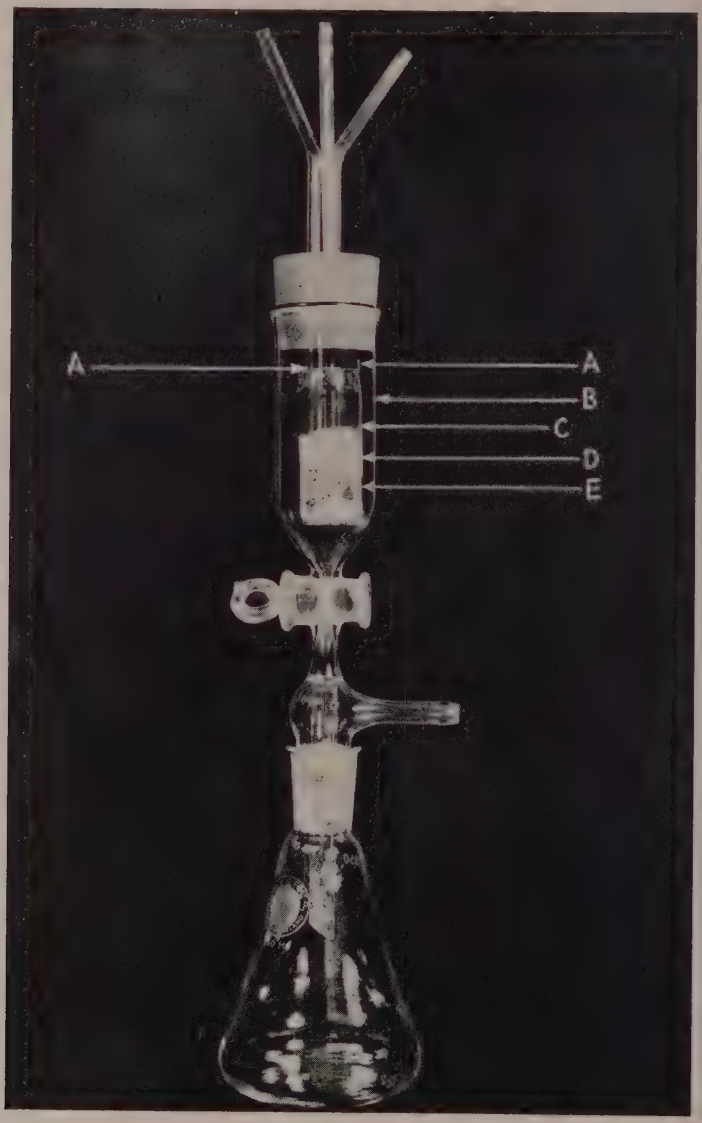

FIG. 1—Sterilization Chamber and Collecting Flask.

A: Wire Hooks suspending Bucket
B: Sterilization Chamber
C: Perforated Glass Bucket
D: Layer of Cotton Wool
E: Seeds

Each bottle is stoppered by a cork through which pass two tubes. One tube projects into the inside of the bottle a short distance and allows delivery of the liquid; the other projects almost to the distal end of the bottle, and allows entry of air to maintain atmospheric pressure,

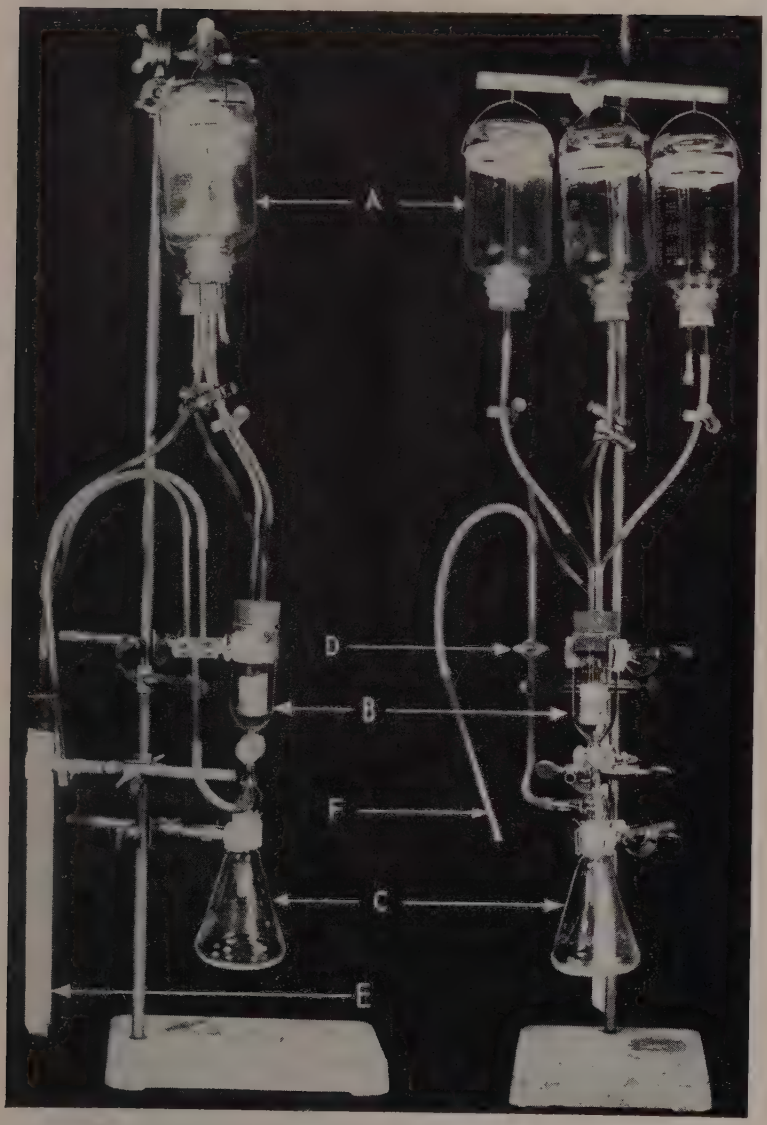

FIG. 2—Complete Assembly of Seed Sterilization Apparatus.

(a) Side view (b) Front view

A: Bottles
B: Sterilization Chamber
C: Collecting Flask
D: Three-way Stopcock
E: Bacterial Filter Tube
F: Lead to Vacuum Pump

In each case, the outer end of the short tube is connected by rubber tubing to one of the glass tubes which enters the sterilization chamber. Control of the fluid from the bottle to the chamber is effected by a pinchcock or a hosecock. Air entering the sterile-water bottle is first

passed through a sterile filter consisting of a tube 30 cm. long and 24 mm. internal diameter packed with cotton wool, thus forming a bacterial filter. From its upper end, a glass tube is connected to a Y-piece. One arm of this Y-piece is connected to the sterile-water bottle, the other to a three-way stopcock, as shown in Fig. 2b.

The side tube of the dropping funnel is attached by rubber tubing to one arm of the three-way stopcock mentioned above, a second arm is attached to a vacuum pump, and the third arm to the bacterial filter tube already described. The arrangement can be seen in Fig. 2a. The attachment of the arms of the stopcock is so arranged that after a vacuum has been applied to the sterilization chamber and collecting flask through one arm of the stopcock, the stopcock plug can then be reversed, thus allowing sterile air to pass from the bacterial filter into the sterilization chamber through the other arm of the stopcock.

With this system of assembly, once the bucket containing the seed has been fixed in position on the wire hooks under the cork, and the cork pressed into the dropping funnel, the various operations required in Gerretsen's method[1] can all be performed without the ingress of non-sterile air to the apparatus.

Method of Sterilization

The bacterial filter tube, the associated tubing, and the bottle of sterile water are sterilized before assembly. The solutions of sterilizing agent and 95 per cent ethyl alcohol are made up and suspended alongside the bottle of sterile water. As mentioned before, the amount of fluid used from each of these bottles is controlled by a pinchcock.

The bottom of the perforated bucket is covered with a thin layer of cotton wool, and the seeds to be sterilized are then placed on top of this layer. They are covered by another layer of cotton wool. The bucket is then attached to the hooks and the cork pressed into the top of the funnel. (Fig. 1.) The interface between the cork and the sides of the funnel is wetted with 95 per cent alcohol applied from a pipette.

A small vacuum is now applied to the sterilization chamber, by opening the stopcock of the dropping funnel for a few seconds. The stopcock is then closed and the chamber filled with 95 per cent alcohol from one of the suspended bottles. The alcohol is afterwards run off into the collecting flask underneath, and a stronger vacuum applied to the seeds. The vacuum is released by allowing sterile air to enter the chamber. The object of this operation is to force alcohol into the small interstices in the seed coat. The alcohol is washed off the seeds with sterile water from the appropriate bottle. The whole treatment with alcohol should not take longer than half to one minute, otherwise the seeds may be unduly damaged and subsequently fail to germinate.

When the seeds have been washed free of alcohol, the sterilizing agent is introduced into the chamber and left there for a short period; the actual time depends upon the particular seed used. After the requisite time has lapsed, the fluid is run off into the collecting flask and the seeds once more washed with sterile water. After this operation, the chamber is opened and the bucket removed to a sterile hood or room; the seeds are plated on to a suitable agar and placed in an incubator for germination. Any microfloral contaminant still remaining on the seeds will grow into the agar and thus indicate any defect in the sterilization technique.

The risk of chance contamination which could occur while transferring the bucket from the sterilization chamber to the sterile atmosphere can be minimized by the following precaution. Before the seeds are removed from the bucket the upper layer of cotton wool is lifted free of the seeds; by means of a pipette, a few drops of alcohol are added to this layer before it is removed from the bucket. This should kill any chance contaminant that has alighted on the top layer of cotton wool or the internal unprotected surface of the bucket.

Up to the present time, the sterilizing agent used in this procedure has been a 1 per cent solution of Aretan, which consists of methoxyethyl mercury chloride together with a dye and soda ash. A 1 per cent solution in water has, when made up, a pH of approximately 8·3. In the Soil Bureau laboratory, the pH is adjusted to pH 7·0 and filtered, with no visible precipitation of the mercurial compound nor apparent loss of potency. A detergent may be added to the sterilizing fluid.

Experiments have also been made with 6·6 per cent calcium hypochlorite and 0·25 per cent mercuric chloride solutions in place of the 1 per cent Aretan solution.

RESULTS

This apparatus has been found suitable for seed sterilization and the production of sterile seedlings of the following plants:

Seed	*Treatment*
Lupin	1 per cent Aretan for 1 hr.
Oats (with the husk removed)	1 per cent Aretan for 1 hr.
Oats (with the husk removed)	6·6 per cent CaOCl for 20 min.
Wheat	6·6 per cent CaOCl for 20 min.
Mustard	0·25 per cent $HgCl_2$ for 2 min.

As yet, it has not been possible to sterilize mustard successfully with Aretan. Gerretsen claims satisfactory sterilization of this seed with a 1 per cent solution of Germisan, another water-soluble mercurial preparation. A sample of Germisan has recently been received from Professor Gerretsen, and results using this preparation will be published in a later note.

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INDEX

VOLUME 33, SECTION A

	PAGE
Actinidia chinensis (see Chinese gooseberries)	113(5)
Aerial top-dressing during 1949, Developments in	1(3)
Aerial top-dressing trials: equipment and flying techniques used, and measurement of distribution of phosphate	54(6)
Agrobacterium tumefaciens (see Crown-gall)	48(3)
Airborne mould spores	78(3)
Ambler M. P. and Vernon T. R.: Airborne mould spores	78(3)
Anatomical characteristics of lamb and mutton carcases. New Zealand lamb and mutton. I	1(5)
Antibiotic substances, Effects of chemicals and . . . on crown-gall (*Agrobacterium tumefaciens*). III	48(3)
Apples, Green-crinkle, a virus disease of	58(3)
Apricots, plums and peaches in New Zealand, Plum-mosaic, a virus disease of	1(2)
Aseptic seedlings, Technique for obtaining	87(6)
Askew H. O., Chittenden E T, and Watson Joyce: Boron, Copper, Manganese and Zinc in the nutrition of the Red Antwerp raspberry ..	13(3)
Atkinson J D, Chamberlain E. E., and Hunter J. A. (see Chamberlain E. E.)	1(2)
Atkinson J. D. and Robbins R. E.: Green-crinkle, a virus disease of apples	58(3)
Bailey F. L. and Padfield C. A. S. (see Padfield C. A. S.)	113(5)
Barnicoat C. R. and Shorland F. B.: New Zealand lamb and mutton. II. Chemical composition of edible tissues	16(5)
Barnicoat C. R.: Experiments on the packing and storage of butter. X. Experiments on predicting the storage life of butter ..	37(1)
Black M. A.: Effect of hot-water treatment on the germination of dreadnought wheat	44(1)
Boron, Copper, Manganese and Zinc in the nutrition of the Red Antwerp raspberry	13(3)
Botanical survey of a peat area between Raumati South and Paraparaumu	78(5)
Boyce S. W., Boyce W. R., Chamberlain E. E., Cumber R. A., Fry P. R., Matthews R. E. F., Newhook F. J., and Strzemienski K.: Preliminary note on yellow-leaf disease of *Phormium*	76(3)
Boyce W. R. *et al.* (see Boyce S. W.)	76(3)
Butter, and Cream, Land-cress taint in. IV	30(4)
V	35(4)
VI	51(4)
Butter, Experiments on the packing and storage of . . . X	37(1)
Campbell D. A.: Developments in aerial top-dressing during 1949 ..	1(3)
Carotene in plant material and faeces, Estimation of	31(6)
Cattle twins, monozygotic, Studies in . . . V, Uniformity trials—growth	17(4)

PAGE

Chamberlain E. E., Atkinson J. D., and Hunter J. A.: Plum-mosaic, a virus disease of plums, peaches and apricots in New Zealand .. 1(2)

Chamberlain E. E. *et al.* (see Boyce S. W.) .. .. .. 76(3)

Changes in the salt content of some saline soils of Lake Ellesmere in Canterbury .. .. 81(6)

Cheese, New Zealand cheddar, Composition of .. .. .. 29(5)

Chemicals and anti-biotic substances, Effects of . . . on crown-gall (*Agrobacterium tumefaciens*). III .. .. 48(3)

Chinese gooseberries (*Actinidia chinensis*): a survey of their behaviour in cool storage at all stages of harvest maturity from May to July 113(5)

Chittenden E. T. and Rigg T. (see Rigg T.) .. .. .. 30(1)

Chittenden E. T., Askew H. O., and Watson Joyce (see Askew H. O.) .. 13(3)

Clarke E. A. and McMeekan C. P.: New Zealand lamb and mutton. I .. 1(5)
III .. 24(5)

Classification of land in Waimea County, Nelson, for flue-cured tobacco 30(1)

Climate and facial eczema in New Zealand. II .. .. .. 53(3)

Clovers, *Coleophoridae* (Lep.) as pests of .. .. 109(5)

Clover, white (*Trifolium repens*), Dissemination of . . . by sheep .. 64(5)

Codling moth (*Cydia pomonella*) in apple orchards, Spray treatments with DDT for control of .. .. 60(4)

Codling moth investigations in Nelson, 1948-49 .. .. .. 90(5)

Coleophoridae (Lep.) as pests of clovers .. .. 109(5)

Comparative animal physiology (Review) .. .. .. 120(5)

Composition, Chemical, of edible tissues. New Zealand lamb and mutton. II .. .. 16(5)

Composition of New Zealand cheddar cheese .. .. .. 29(5)

Control grazing of land-cress infested pastures. Land-cress taint in cream and butter. VI .. .. 51(4)

Control of weeds in tobacco seedling beds .. .. 74(6)

Copper, Boron, Manganese and Zinc in the nutrition of the Red Antwerp raspberry .. .. 13(3)

Coronopus didymus, Land-cress, Relation of the essential oils of . . . to the occurrence of land-cress taint in cream and butter. IV .. 30(4)

Coup M. R. and Dunlop A. A.: Digestibility trials with *Paspalum dilatatum* .. .. 1(4)

Cream and Butter, Land-cress taint in . . . IV .. .. .. 30(4)

Crown-gall (*Agrobacterium tumefaciens*), Effects of chemicals and anti-biotic substances on. III .. .. 48(3)

Cruickshank I. A. M.: Fusarium foot-root of peas in New Zealand .. 62(3)

Cruickshank I. A. M.: Pea Wilt in New Zealand .. .. .. 75(4)

Cruickshank I. A. M.: Resistance of linseed and linen flax varieties to flax rust (*Melampsora lini*) in New Zealand. II .. .. 62(2)

Culliford P. J., Wright A. C. S., and Gridley E. J. S. (see Wright A. C. S.) .. .. 39(3)

Cumber R. A. *et al.* (see Boyce S. W.) .. .. 76(3)

Cyanogenetic glucoside of white clover, Preparation of the .. .. 56(1)

Cydia pomonella (see Codling moth) .. .. 60(4)

DDT for control of codling moth (*Cydia pomonella*) in apple orchards. Spray treatments with .. .. 60(4)

Deficiency, magnesium, in tomato-leaves .. .. 52(2)

Deterioration of soil structure in a South Canterbury soil .. .. 40(6)

Developments in aerial top-dressing during 1949 .. .. .. 1(3)

Digestibility trials with *Paspalum dilatatum* .. .. .. 1(4)

PAGE

Directory of New Zealand Science (Review) .. .. .. 118(5)
Dissemination of white clover (*Trifolium repens*) by sheep .. .. 64(5)
Dougherty apple leaves and fruit. Mineral and nitrogen status of . . . under different fertilizer treatments .. .. 66(4)
Dunlop A. A. and Coup M. R. (see Coup M. R.) .. .. .. 1(4)
Dumbleton L. J.: *Coleophoridae* (Lep.) as pests of clovers .. .. 109(5)
Dye D. W.: Effects of chemicals and anti-biotic substances on crown-gall (*Agrobacterium tumefaciens*). III .. .. 48(3)

Effect of moisture content on the viability of Italian ryegrass seed in storage .. .. 58(2)
Effect of hot-water treatment on the germination of dreadnought wheat 44(1)
Effects of chemicals and anti-biotic substances on crown-gall (*Agrobacterium tumefaciens*). III .. .. 48(3)
IV .. .. 104(5)
Effect of fumigants on growth of soil fungi in culture. Soil disinfection. XII .. .. 69(6)
Estimation of carotene in plant material and faeces .. .. 31(6)
Evans L. T.: Changes in the salt content of some saline soils at Lake Ellesmere in Canterbury .. .. 81(6)
Ewer T. K. and Sinclair D. P.: Lamb-fattening trials on the Canterbury Plains .. .. 1(6)
Experiments on the packing and storage of butter. X. Experiments on predicting the storage life of butter .. .. 37(1)

Facial eczema. Climate and . . . in New Zealand. II .. .. .. 53(3)
Fat lamb carcass, Influence of the type of ewe upon the type of .. 45(2)
Flash pasteurization and vacreator vacuum pasteurization of land-cress contaminated cream. Land-cress taint in cream and butter. V .. 35(4)
Flax rust (*Melampsora lini*), Resistance of linseed and linen-flax varieties to . . . in New Zealand. II .. .. 62(2)
Foot-rot (*Phytophthora cryptogea*) of tomatoes, Control of, Soil disinfection. XI .. .. 71(4)
Fraser J. G. and Melville J. (see Melville J.) .. .. .. 56(1)
Fry P. R. *et al.* (see Boyce S. W.) .. .. 76(3)
Fry P. R.: Lettuce mosaic .. .. 52(5)
Fumigants, Effect of . . . on growth of soil fungi in culture. Soil disinfection. XII .. .. 69(6)
Fusarium foot-root of peas in New Zealand .. .. .. 62(3)

Germination of dreadnought wheat, Effect of hot-water treatment on 44(1)
Glucoside, cyanogenetic, of white clover, Preparation of the .. .. 56(1)
Goet H.: Studies on some New Zealand Romney Marsh stud flocks. V. Losses in ewes and lambs .. .. 28(2)
Gorman L. W. and Greenwood R. M.: Effect of moisture content on the viability of Italian ryegrass seed in storage .. .. .. 58(2)
Grecnall A. F., Quill S. G., and Stephenson J.: Aerial top-dressing trials: equipment and flying technique used and measurement of distribution of phosphate .. .. 54(6)
Green-crinkle, a virus disease of apples .. .. 58(3)
Greenwood R. M. and Gorman L. W. (see Gorman L. W.) .. .. 58(2)
Gridley E. J. S., Wright A. C. S., and Culliford P. J. (see Wright A. C. S.) .. .. 39(3)

Hamilton Avis: Codling moth investigations in Nelson, 1948-49 .. 90(5)
Hancock John: Studies on monozygotic cattle twins. V. Uniformity trials—growth .. .. 17(4)

PAGE

Head smut of maize, Preliminary report on control of. Soil disinfection. X .. .. 37(2)
Hot-water treatment, Effect of . . . on the germination of dreadnought wheat .. .. 44(1)
Hunter J. A., Chamberlain E. E., and Atkinson J. D. (see Chamberlain E. E.) .. .. 1(2)

Influence of the type of ewe upon the type of fat lamb carcass .. 45(2)

Jacks H.: Seed disinfection. I. Preliminary selection of vegetable-seed protectants .. .. 27(3)
Jacks H.: Soil disinfection. X. Preliminary report on control of head smut (*Sorosporium reilianum*) of Maize (*Zea mays*) .. .. 37(2)
XI. Control of foot-rot (*Phytophthora cryptogea*) of tomatoes .. 71(4)
Jacks H. and Smith H. C.: Soil disinfection. XII. Effects of fumigants on growth of soil fungi in culture .. .. 69(6)
Johannesson J. K.: Magnesium deficiency in tomato leaves .. .. 52(2)
Johnston H. W.: Technique for obtaining aseptic seedlings .. .. 87(6)

Lake Ellesmere in Canterbury, Changes in the salt content of some saline soil at .. .. 81(6)
Lamb and Mutton, New Zealand .. .. 1(5)
Lamb fattening trials on the Canterbury Plains .. .. .. 1(6)
Land-cress taint in cream and butter.
IV. The relation of the essential oils of land-cress (*Coronopus didymus*) to the occurrence of land-cress taint in cream and butter 30(4)
V. Flash pasteurization and vacreator-vacuum pasteurization of land-cress contaminated cream .. .. 35(4)
VI. Further experiments on the control grazing of land-cress infested pastures .. .. 51(4)
Land in Waimea County, Nelson, Classification of . . . for flue-cured tobacco .. .. 30(1)
Lateral growth in flue-cured tobacco, Control of . . . by chemicals .. 78(6)
Leaf roller (*Tortrix postvittana*) in apple orchards, Spray treatments for control of .. .. 98(5)
Lettuce mosaic .. .. 52(5)
Linen-flax varieties, Resistance of linseed and . . . to flax rust (*Melampsora lini*) in New Zealand. II .. .. 62(2)
Linseed and linen-flax varieties, Resistance of . . . to flax rust (*Melampsora lini*) in New Zealand. II .. .. 62(2)
Losses in ewes and lambs. Studies on some New Zealand Romney Marsh stud flocks. V .. .. 28(2)

McDowall F. H.: The Composition of New Zealand cheddar cheese .. 29(5)
McDowall F. H., McDowell A. K. R., Morton I. D., Singleton J. A., and O'Dea J. J.: Land-cress taint in cream and butter. V .. .. 35(4)
McDowall F. H., Morton I. D., and McDowell A. K. R.: Land-cress taint in cream and butter. IV .. .. 30(4)
McDowall F. H., Singleton J. A., and O'Dea J. J.: Land-cress taint in cream and butter. VI .. .. 51(4)
McDowall F. H., Singleton J. A., and O'Dea J. J.: Pasteurization of cream at high temperature in the vacreator vacuum-pasteurizer in relation to the quality of butter .. .. 53(4)
McDowell A. K. R., McDowall F. H., and Morton I. D. (see McDowall F. H.) .. .. 30(4)
McDowell A. K. R. *et al.* (see McDowall F. H.) .. .. .. 35(4)
McGillivray W. A.: The estimation of carotene in plant material and faeces .. .. 31(6)
McMeekan C. P. and Clarke E. A. (see Clarke E. A.) .. .. 1, 24(5)

PAGE

McMeekan C. P. and Walker D. E.: Influence of the type of ewe upon the type of fat lamb carcass .. .. 45(2)
Magnesium deficiency in tomato leaves .. .. 52(2)
Maize (*Zea mays*), Preliminary report on control of head smut (*Sorosporium reilianum*) of, Soil disinfection. X .. .. .. 37(2)
Manganese, Copper, Boron and Zinc in the nutrition of the Red Antwerp raspberry .. .. 13(3)
Matthews R. E. F. *et al.* (see Boyce S. W.) .. .. .. 76(3)
Measurement of the distribution of granular superphosphate from aeroplanes .. .. 17(2)
Melampsora lini (see Flax rust) .. .. 62(2)
Melville J. and Fraser J. G.: Preparation of the cyanogenetic glucoside of white clover .. .. 56(1)
Miller, J.: Measurement of the distribution of granular superphosphate from aeroplanes .. .. 17(2)
Mineral and nitrogen status of Dougherty apple leaves and fruit under different fertilizer treatments .. .. 66(4)
Moar N. T.: A botanical survey of a peat area between Raumati South and Paraparaumu .. .. 78(5)
Monozygotic cattle twins, Studies in . . . V. Uniformity trials—growth 17(4)
Morton I. D., McDowall F. H., and McDowell A. K. R. (see McDowall F. H.) .. .. 30(4)
Morton I. D. *et al.* (see McDowall F. H.) .. .. 35(4)
Mosaic, Lettuce .. .. 52(2)
Mould spores, Airborne .. .. 78(3)
Mutton, and Lamb, New Zealand .. .. 1(5)

Newhook F. J. *et al.* (see Boyce S. W.) .. .. 76(3)
New Zealand lamb and mutton.
I. Anatomical characteristics of lamb and mutton carcases .. 1(5)
II. Chemical composition of edible tissues .. .. .. 16(5)
III. The nutritive status of lamb and mutton carcases .. .. 24(5)
Nitrogen and mineral status of Dougherty apple leaves and fruit under different fertilizer treatments .. .. 66(4)
Nutritive status of lamb and mutton carcases. New Zealand lamb and mutton. III .. .. 24(5)

O'Dea J. J. *et al.* (see McDowall F. H.) .. .. 35(4)
O'Dea J. J., McDowall F. H., and Singleton J. A. (see McDowall F. H.) 51(1)

Packard R. Q. and Raeside J. D.: Deterioration of soil structure in a South Canterbury soil .. .. 40(6)
Padfield C. A. S. and Bailey F. L.: Chinese gooseberries (*Actinidia chinensis*) : a survey of their behaviour in cool storage at all stages of harvest maturity from May to July .. .. .. 113(5)
Paraparaumu, Botanical survey of peat area between Raumati South and .. .. 78(5)
Paspalum dilatatum, Digestibility trials with .. .. .. 1(4)
Pasteurization, flash, and vacreator vacuum pasteurization of land-cress contaminated cream. Land-cress taint in cream and butter. V .. 35(1)
Pasteurization of cream at high temperatures in the vacreator vacuum-pasteurizer in relation to the quality of butter .. .. .. 53(4)
Pasture measurement, Technique of .. .. 1(1)
Peaches, plums and apricots in New Zealand, Plum-mosaic, a virus disease of .. .. 1(2)
Peas in New Zealand, Fusarium foot-rot of .. .. .. 62(3)
Pea wilt in New Zealand .. .. 75(4)
Peat area between Raumati South and Paraparaumu, Botanicl Survey of 78(5)

PAGE

Pests of clovers, *Coleophoridae* (Lep.) as .. .. 109(5)
Phormium, Preliminary note on yellow-leaf disease of .. .. 76(3)
Phytophthora cryptogea (see Foot-rot of tomatoes) .. .. 71(4)
Phytophthora fragariae (see Red-core of strawberries) .. .. 49(1)
Physical chemistry for pre-medical students (Review) .. .. 117(5)
Plum-mosaic, a virus disease of plums, peaches and apricots in N.Z. 1(2)
Plums, peaches, and apricots in N.Z., Plum-mosaic, a virus disease of 1(2)
Preliminary note on Yellow-leaf disease of *Phormium* .. .. 76(3)
Preparation of the cyanogenetic glucoside of white clover .. .. 56(1)
"Problem" soil, Rangitoto sandy loam .. .. 39(3)
Protectants, vegetable seed, Preliminary selection of. Seed disinfection. I 27(3)

Quill S. G., Greenall A. F., and Stephenson J. (see Greenall A. F.) .. 54(6)

Raeside J. D. and Packard R. Q. (see Packard R. Q.) .. .. 40(6)
Rangitoto sandy loam—a "problem" soil .. .. 39(3)
Raspberry, Red Antwerp, Boron, Copper, Manganese and Zinc in the nutrition of .. .. 13(3)
Raumati South and Paraparaumu, Botanical survey of a peat area between .. .. 78(5)
Red Antwerp Raspberry, Boron, Copper, Manganese and Zinc in the nutrition of .. .. 13(3)
Red-core (*Phytophthora fragariae*) of strawberries .. .. 49(1)
Resistance of linseed and linen-flax varieties to flax rust (*Melampsora lini*) in New Zealand. II .. .. 62(2)
Rigg T. and Chittenden E. T.: Classification of land in Waimea County, Nelson, for flue-cured tobacco .. .. 30(1)
Robbins R. E. and Atkinson J. D. (see Atkinson J. D.) .. .. 58(3)
Romney Marsh stud flocks, New Zealand, Studies on .. .. 28(2)
Ryegrass, Italian, Effect of moisture content on the viability of . . . seed in storage .. .. 58(2)

Saline soils at Lake Ellesmere in Canterbury, Changes in the salt content of some .. .. 81(6)
Sears P. D.; Technique of pasture measurement .. .. .. 1(1)
Seed disinfection. I. Preliminary selection of vegetable-seed protectants 27(3)
Sheep, Dissemination of white clover by .. .. 64(5)
Shorland F. B. and Barnicoat C. R. (see Barnicoat C. R.) .. .. 16(5)
Simmons Pamela: Climate and facial eczema in New Zealand. II. .. 53(3)
Sinclair D. P. and Ewer T. K. (see Ewer T. K.) .. .. .. 1(6)
Singleton J. A., McDowall F. H., and O'Dea J. J. (see McDowall F. H.) 51(4)
Smith H. C.: Red-core (*Phytophthora fragariae*) of strawberries .. 49(1)
Smith H. C. and Jacks H. (see Jacks H.) .. .. 69(6)
Soil disinfection. X. Preliminary report on control of head smut (*Sorosporium reilianum*) of maize (*Zea mays*) .. .. .. 37(2)
XI. Control of foot-rot (*Phytophthora cryptogea*) of tomatoes .. 71(4)
Soil fungi, Effect of fumigants on the growth of . . . in culture. Soil disinfection. XII .. .. 69(6)
Soils of South-Western Southland .. .. 66(3)
Soil structure in a South Canterbury soil, Deterioration of .. .. 40(6)
Sorosporium reilianum, Head smut of maize, Preliminary report on control of. Soil disinfection. X .. .. 37(2)
South Canterbury soil, Deterioration of soil structure in a .. .. 40(6)
South-Western Southland, Soils of .. .. 66(3)
Spray treatments for control of leaf roller (*Tortrix postvittana*) in apple orchards .. .. 98(5)
Strawberries, Red core (*Phytophthora fragariae*) of .. .. .. 49(1)

PAGE

Strzemienski K. *et al.* (see Boyce S. W.) .. .. .. 76(3)
Singleton J. A. *et al.* (see McDowall F. H.) .. .. .. 35(4)
Studies on monozygotic cattle twins. V. Uniformity trials—growth .. 17(4)
Studies on some New Zealand Romney Marsh stud flocks. V. Losses in ewes and lambs .. .. 28(2)
Suckling F. E. T.: Dissemination of white clover (*Trifolium repens*) by sheep .. .. 64(5)
Superphosphate, granular, Measurement of the distribution of . . . from aeroplanes .. .. 17(2)

Taylor G. G.: Spray treatments for control of leaf roller (*Tortrix postvittana*) in apple orchards .. .. 98(5)
Taylor, G. G.: Spray treatments with DDT for control of Codling moth (*Cydia pomonella*) in apple orchards .. .. 60(4)
Technique for obtaining aseptic seedlings .. .. 87(6)
Technique of pasture measurement .. .. 1(1)
Thomson R.: Control of lateral growth in flue-cured tobacco by chemicals 78(6)
Thomson R.: Control of weeds in tobacco seedling beds .. .. 74(6)
Tobacco, flue-cured, Control of lateral growth in . . . by chemicals .. 78(6)
Tobacco, flue-cured, Classification of land in Waimea County, Nelson, for 30(1)
Tobacco seedling beds, Control of weeds in .. .. 74(6)
Tomatoes, Control of foot-rot of. Soil disinfection. XI .. .. 71(4)
Tomato leaves, Magnesium deficiency in .. .. 52(2)
Tortrix postvittana (see Leaf roller) .. .. 98(5)
Trifolium repens (see White clover) .. .. 64(5)
Twins, Monozygotic cattle, Studies on . . . V. Uniformity trials—growth 17(4)

Vacreator vacuum-pasteurizer, Pasteurization of cream at high temperatures in the . . . in relation to the quality of butter .. .. 53(4)
Vacreator vacuum-pasteurization and flash pasteurization of land-cress contaminated cream, Land-cress taint in cream and butter. V .. 35(4)
Vegetable-seed protectants, Preliminary selection of. Seed disinfection. I 27(3)
Vernon T. R. and Ambler M. P. (see Ambler M. P.) .. .. 78(3)
Viability of Italian ryegrass seed in storage, Effect of moisture content on .. .. 58(2)
Virus disease of apples, Green-crinkle .. .. 58(3)
Virus disease of plums, peaches and apricots in New Zealand, Plum mosaic .. .. 1(2)

Waimea County, Nelson, Classification of land in . . . for flue-cured tobacco .. .. 30(1)
Walker D. E. and McMeekan C. P. (see McMeekan C. P.) .. .. 45(2)
Watson Joyce: Mineral and nitrogen status of Dougherty apple leaves and fruit under different fertilizer treatments .. .. .. 66(4)
Watson Joyce, Askew H. O., and Chittenden E. T. (see Askew H. O.) 27(3)
Weeds in tobacco seedling beds, Control of .. .. 74(6)
Wheat, Dreadnought, Effect of hot-water treatment on the germination of .. .. 44(1)
White clover (*Trifolium repens*), Dissemination of . . . by sheep .. 64(5)
White clover, Preparation of the cyanogenetic glucoside of .. .. 56(1)
Wright A. C. S., Gridley E. J. S., and Culliford P. J.: Rangitoto sandy loam—a "problem" soil .. .. 39(3)
Wright A. C. S.: Soils of South Western Southland .. .. .. 66(3)

Yellow-leaf disease of *Phormium*, Preliminary note on .. .. 76(3)

Zinc, Manganese, Copper and Boron in the nutrition of the Red Antwerp raspberry .. .. 13(3)

INTER-COMMONWEALTH POST-GRADUATE SCHOLARSHIPS IN SCIENCE

◆

The Royal Society Empire Scientific Conference and the British Commonwealth Scientific Official Conference in 1946 recommended the preparation of a list of post-graduate scholarships available for scientific study within the Commonwealth. The task of compiling the list was assigned to the British Commonwealth of Nations Scientific Liaison Office in London.

The entries in this list which has now been prepared are set out in tabular form showing, in addition to the names of the scholarships and the agencies awarding them, details of the fields of study, where tenable, duration and value, closing dates for applications, and the addresses to which these should be sent. There are more than 350 separate entries in the list: many of these cover a number of scholarships, so that the total number of available awards is much greater. The list is therefore a valuable work of reference for students and educational authorities.

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